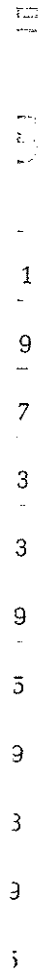


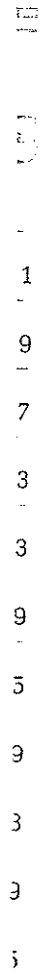
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1. Teachers should see that the pupil's name is clearly written in ink in the spaces above in every book issued.
2. The following terms should be used in recording the condition of the book: New; Good; Fair; Poor; Bad.

1. Teachers should see that the pupil's name is clearly written in ink in the spaces above in every book issued.
2. The following terms should be used in recording the condition of the book: New; Good; Fair; Poor; Bad.

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---

### BEFORE YOU BEGIN . . .

You are about to take a fabulous trip. On much of your trip you'll be exploring things you know something about. But you will be looking at them in a new way.

In this book you'll learn about things you see every day: magnets, compasses, and motors, for instance. You will learn how they are made and how they work. You'll learn about things that may be new to you, too!

On this guided tour you will also discover how a thermometer and refrigerator work and how heat from the sun reaches the earth. You'll learn how to make electricity, too!

Your guide book is set up in a special way. Each stop-over, or Aim, begins with the things you'll need to know. This is followed by a series of exercises. Take your time on these. And look back to the Aim page when you're not sure of an answer. There will be experiments along the way—and a few surprises, too!

So get ready. Your trip is about to begin. Have a good time . . . and, oh yes, don't forget to write!

---

## SCIENCE SAFETY

Science is the study of the world around you. The study of any branch of science includes "learning by doing." Investigations, experiments, demonstrations. Activities in which you are involved. You make things happen.

Safety is a very important part of these activities. Even if you are only reading about an investigation, you should know about the safety precautions that **MUST** be taken. The following **SAFETY ALERT SYMBOLS** are designed to call these precautions to your attention. They appear on pages wherever any of these dangers are present.



Safety Goggles



Lab Apron  
or Coat

Safety goggles and a laboratory apron or coat should be worn for all activities or investigations.



Open Flame

When working near an open flame, be sure that hair and loose clothing are secured in some manner.



Poison

Many chemicals are poisonous, or toxic. Never taste, touch, or smell any unknown substance unless told to do so by your teacher.



Caustic Substances

Caustic (KAW stik) substances can burn your skin, eyes, and clothing. Handle these substances with extreme care. Acids and bases (such as lye) are caustic.



Toxic Vapors

Never inhale any vapors directly. To test the odor of a substance, use your hand to waft the vapors to your nose.



Sharp Objects

Always handle sharp objects with great care.



Broken Glass

Glassware, such as beakers, test tubes, glass tubing, and thermometers should be handled very carefully to avoid breakage. Never pick up broken glass with your bare hands.



Electric Shock

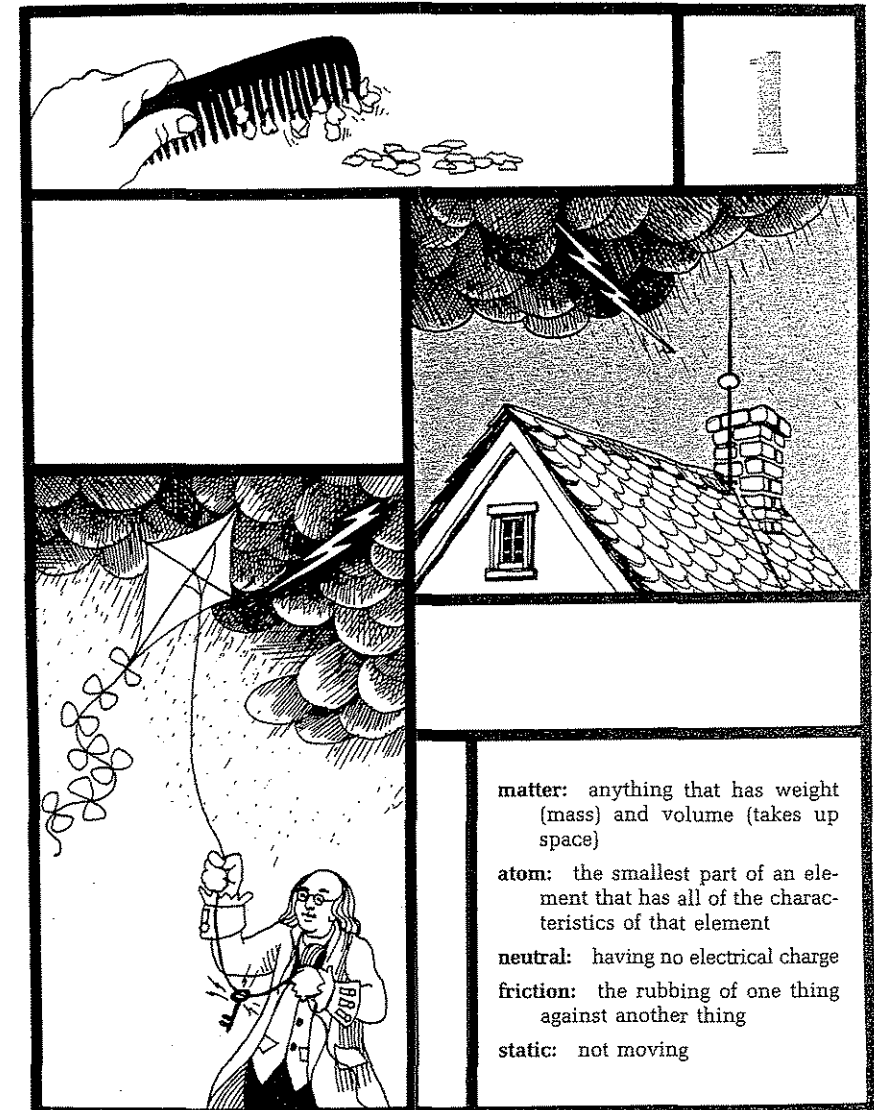
Never use electrical appliances near water or other liquids. Always inspect wiring for worn or broken insulation. Unplug all electric cords when not in use.



Hot Objects

When handling hot objects, use tongs or padded gloves. Never set hot objects directly on a desk or table top. Set them on a heat-resistant pad.

## WHAT IS STATIC ELECTRICITY?



**matter:** anything that has weight (mass) and volume (takes up space)

**atom:** the smallest part of an element that has all of the characteristics of that element

**neutral:** having no electrical charge

**friction:** the rubbing of one thing against another thing

**static:** not moving

# AIM | What is static electricity?

1

Did you ever walk across a rug, touch something, and get a shock? That shock was caused by static electricity [STAT ik i lek TRISS it ee]. Static means not moving. Static electricity is electricity that is not moving along a path. What causes static electricity?

To understand what causes static electricity, you have to know about the atom. Scientists have learned that all matter is made up of tiny parts called atoms. An atom is the smallest part of an element that has all of the properties of that element.

Atoms have charges of electrical energy. There are two kinds of charges. There are positive (plus or +) charges. There are also negative (minus or -) charges. An atom has both positive and negative charges.

Usually, an atom has the same number of positive charges as it has negative charges. The positive and negative charges cancel each other out. The charges are balanced. The atom is neutral [NEW trul]. A neutral atom has no electrical charge.

Sometimes, the positive and negative charges of an atom are not equal. Then the atom is not neutral. If the atom has more positive charges than negative charges, the whole atom has a positive charge. If there are more negative charges, the whole atom has a negative charge.

Matter that has charged atoms has static electricity.

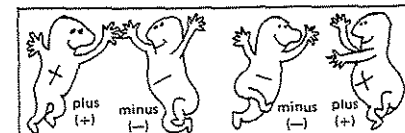
Static electricity can develop in several ways. One way is by rubbing certain substances together. The rubbing of one object against another object is called friction [FRIK shun]. Static electricity is sometimes called friction electricity.

Static electricity is not the same as the electricity we use for light bulbs, motors, toasters and other "electrical" appliances.

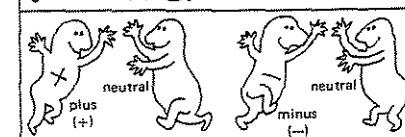
## PLUS AND MINUS CHARGES

Charged matter may have a plus (+) charge or a minus (-) charge.

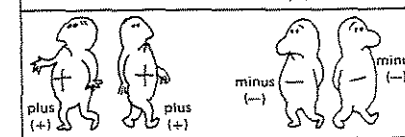
■ Opposite charges attract.



■ A plus or minus charge and a neutral charge also attract.



■ Same charges repel.



Four of these pairs will attract. Two pairs will repel.

Which pairs will attract?

+ and +

Which pairs will repel?

+ and -

Write your answers below.

- and -

- and +

neutral and +

neutral and -

ATTRACT

REPEL



The word "electricity" comes from the Greek word meaning "amber."

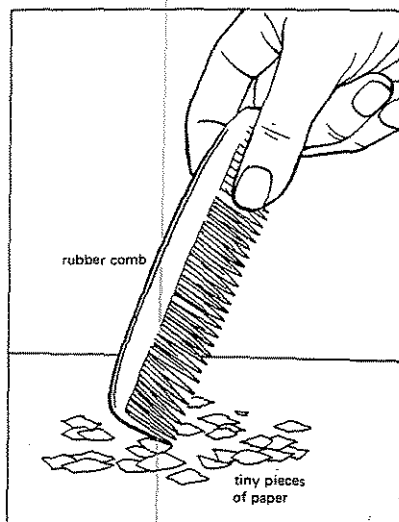
Amber is hardened tree sap.

Early Greeks experimented with amber. They rubbed amber against fur or cloth. This caused a slight spark and a "crackling" sound. After the amber was rubbed, it was able to pick up feathers or thin wood chips.

## EXPERIMENTING WITH STATIC ELECTRICITY

First do step 1. Then do step 2. Answer the questions next to each step.

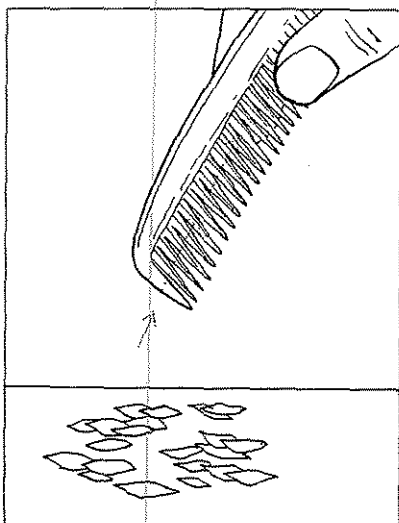
A.



### STEP 1

1. Touch a rubber comb to a few tiny pieces of paper. (See Figure A.)

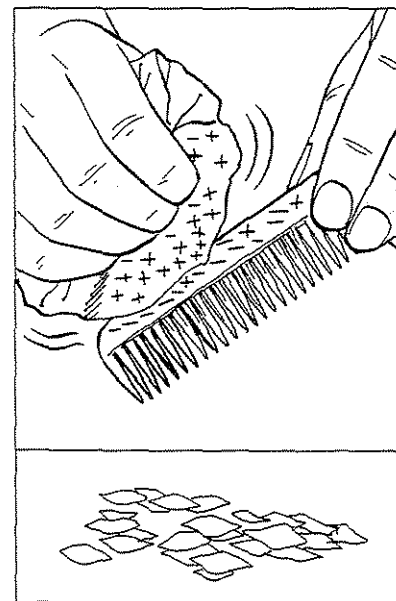
B.



Then lift the comb. (See Figure B.)

- a) The comb \_\_\_\_\_ does, does not  
pick up the paper.
- b) The comb \_\_\_\_\_ is, is not  
charged.
- c) The paper \_\_\_\_\_ is, is not  
charged.
- d) This shows that objects with no  
charge \_\_\_\_\_ do, do not  
attract each other.

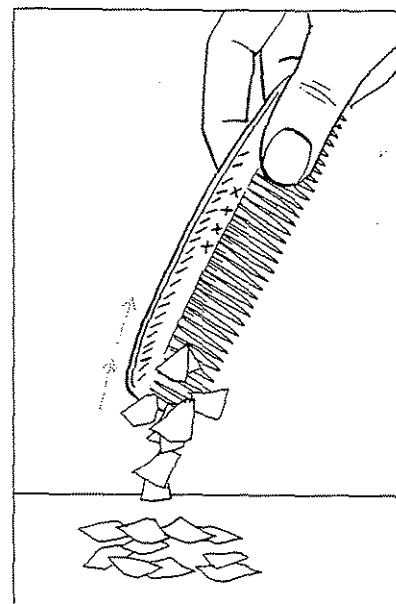
C.



### STEP 2

2. Rub the comb with a piece of cloth or fur. [Combing your hair may also do the job.] This rubbing causes minus (negative) charges to move from the cloth to the comb. (Figure C.)

D.



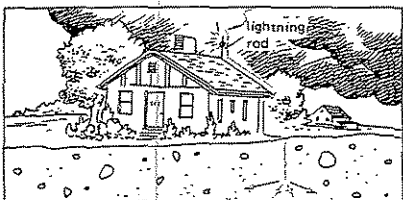
Touch the comb to the pieces of paper. Then lift the comb. (Figure D.)

- a) The comb \_\_\_\_\_ does, does not  
pick up the paper.
- b) The comb \_\_\_\_\_ has, has not  
become charged.
- c) The comb now
  - a) has a plus charge.
  - b) has a minus charge.
  - c) is neutral.
- d) The paper
  - a) has a plus charge.
  - b) has a minus charge.
  - c) is neutral.
- e) This shows that a charged object  
\_\_\_\_\_ does, does not  
attract a neu-  
tral object.

## LIGHTNING

Clouds can build strong static electricity. Scientists believe that static electricity causes lightning.

Lightning is very dangerous. In the United States alone, lightning kills nearly 400 people every year. About 1,500 more are injured.



Every house should have a lightning rod. The lightning hits the lightning rod instead of the house.

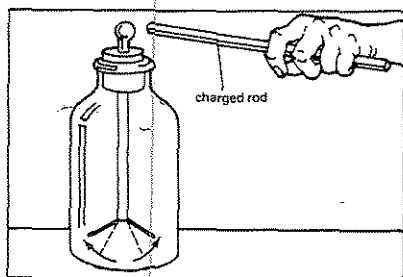
The electricity then travels through a wire into the ground. No one gets hurt.

### Lightning Safety Rules

During a lightning storm . . .

1. DON'T run onto an open field.
2. DON'T stay under a tree.
3. DO stay indoors or find a place indoors.
4. If you are in a car during a lightning storm, DO stay there. [Can you figure out why?]
5. If you are swimming, DO get out of the water.

WHAT DOES THE PICTURE SHOW? Look at the picture. Then answer the questions.



An electroscope is a simple instrument. It tells us if an object has static electricity.

If you hold a charged object near the tip of an electroscope, the leaves move apart.

The leaves move apart because they have \_\_\_\_\_ charges.  
same, opposite

MULTIPLE CHOICE On the space on the right, write the letter that best completes each sentence.

1. An atom has \_\_\_\_\_  
a) only plus charges.  
b) only minus charges.  
c) plus and minus charges.
2. Usually, an atom has \_\_\_\_\_  
a) the same number of plus and minus charges.  
b) more plus charges than minus charges.  
c) more minus charges than plus charges.
3. "Neutral" charge means \_\_\_\_\_  
a) plus charge.  
b) no charge.  
c) minus charge.
4. Usually, an atom is \_\_\_\_\_  
a) charged.  
b) not charged.
5. Charged matter has \_\_\_\_\_  
a) no electricity.  
b) moving electricity.  
c) static electricity.
6. Static electricity \_\_\_\_\_  
a) moves in a path.  
b) does not move in a path.  
c) is neutral.
7. To make 100 minus charges neutral, you need \_\_\_\_\_  
a) 50 minus charges and 50 plus charges.  
b) 100 minus charges.  
c) 100 plus charges.
8. Same charges \_\_\_\_\_  
a) attract.  
b) repel.  
c) do not attract or repel.
9. Opposite charges \_\_\_\_\_  
a) attract.  
b) repel.  
c) do not attract or repel.
10. Static electricity can come from \_\_\_\_\_  
a) batteries.  
b) rubbing.  
c) ancient Greece.

**MATCHING** Match the two lists. Write the correct letter on the line next to each number.

- |          |                  |                                 |
|----------|------------------|---------------------------------|
| 1. _____ | opposite charges | a) means "not moving"           |
| 2. _____ | neutral          | b) repel                        |
| 3. _____ | rubbing          | c) attract                      |
| 4. _____ | static           | d) charges are balanced         |
| 5. _____ | same charges     | e) can cause static electricity |

**TEACHING POINT** Benjamin Franklin was a famous American. He invented many useful things.

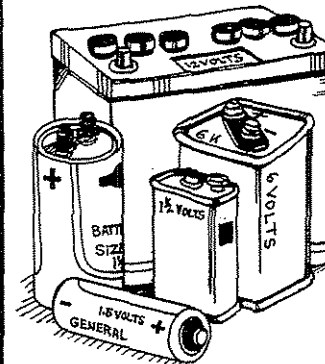
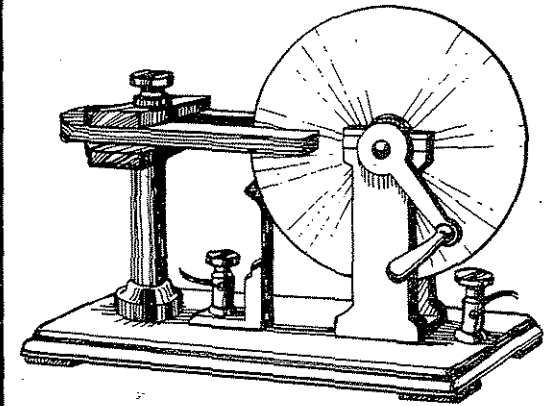
Franklin did many experiments with electricity. It is said that during one experiment he flew a kite during a thunderstorm.

1. Why should you not do this? \_\_\_\_\_
2. What can a kite act as? \_\_\_\_\_



## WHAT IS CURRENT ELECTRICITY?

2



circuit: a path that ends at the same point where it starts  
generator: machine that makes electricity



## AIM | What is current electricity?

### 2

Think of all the ways you use electricity each day. You awake to an alarm clock or radio, turn on an electric light, use an electric toothbrush, or make toast. You watch television, listen to records, use air conditioners. Just think about lights. Almost every place you go you find electrical lighting.

About one hundred years ago, there was no electricity in homes, schools, factories, and offices. Try to imagine your life without electricity!

The electricity that works all your electrical appliances is called *current electricity*. A current is a flow of water. Current electricity is a flow of electrons [i LECK tronz]. Electrons are the parts of the atom that have a negative charge. There is another part of the atom that has a positive charge.

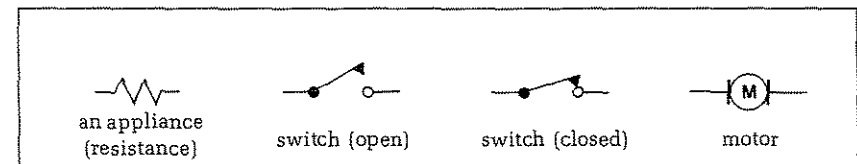
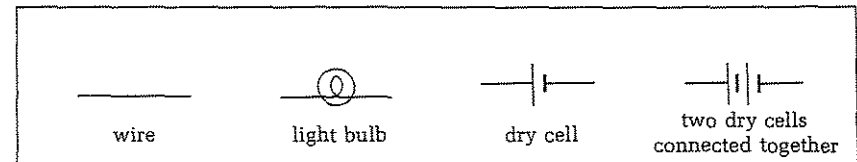
Electrons move along a path called a *circuit* [SIR cut]. While the electrons are moving, the circuit is *complete*. If the electrons stop moving, the circuit is *incomplete* and the electricity stops.

Some of our electricity comes from batteries. Small batteries like those used for flashlights are called *dry cells*. Most of our electricity comes from machines called *generators* [JEN uh ray terz].

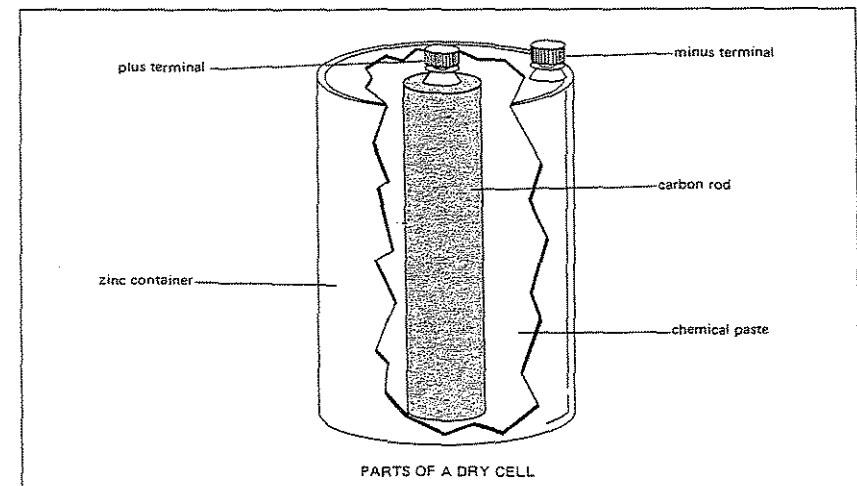
Each year, the world uses more and more electricity. More and more generators are needed.

## SOME COMMON ELECTRICAL SYMBOLS

A.



B.



## PARTS OF A DRY CELL

A dry cell changes chemical energy to electric energy.

Dry cells come in many different sizes and strengths.

WHAT DO THE PICTURES SHOW?

Look at each picture. Then answer the questions.

Anything that works with electricity is called an electrical device.

We call some electrical devices, appliances. Electricians call them loads.

1. Figure C shows some electrical devices. How many can you name?

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2. How many other electrical devices can you name?

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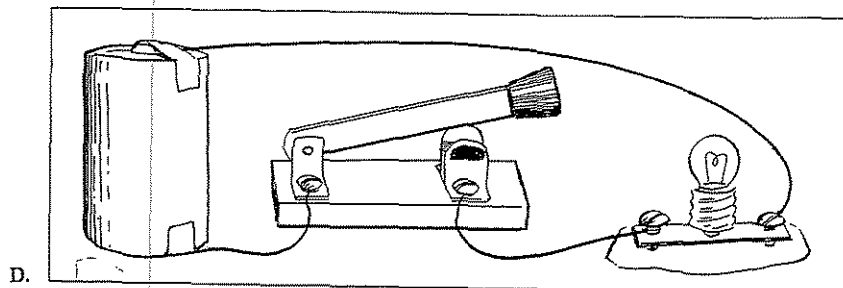
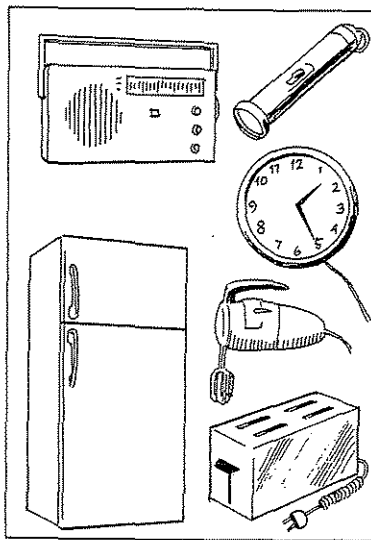
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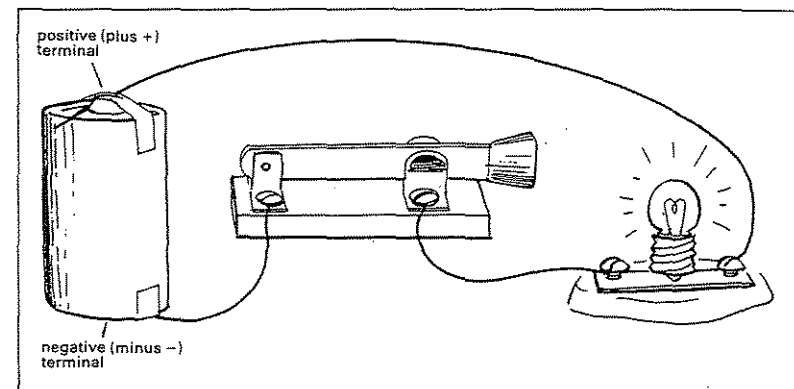
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D.

- Is this circuit complete or incomplete? \_\_\_\_\_
- Are electrons moving? \_\_\_\_\_
- Does the bulb light up? \_\_\_\_\_



E.

- Is this circuit complete or incomplete? \_\_\_\_\_
- Are electrons moving? \_\_\_\_\_
- Does the bulb light up? \_\_\_\_\_
- Electricity flows from minus to plus. Draw arrows near the wires, the switch, and battery to show this path.

COMPLETING SENTENCES

Complete the sentences with the choices below.

|            |                   |                          |
|------------|-------------------|--------------------------|
| complete   | minus             | plus                     |
| generators | move along a path | circuit                  |
| incomplete | toaster           | do not move along a path |

- In static electricity, electrons \_\_\_\_\_.
- In current electricity, electrons \_\_\_\_\_.
- The path along which electrons move is called a \_\_\_\_\_.
- Electrons do not move in an \_\_\_\_\_ circuit.
- Electrons do flow in a \_\_\_\_\_ circuit.
- Electrons leave a dry cell through the \_\_\_\_\_ terminal.
- Electrons return to a dry cell through the \_\_\_\_\_ terminal.
- Large amounts of electricity are made by \_\_\_\_\_.
- An example of an electrical appliance is a \_\_\_\_\_.

### CAN YOU IDENTIFY THESE ELECTRICAL SYMBOLS?

- |                                                                                      |       |                                                                                      |       |
|--------------------------------------------------------------------------------------|-------|--------------------------------------------------------------------------------------|-------|
| 1.  | _____ | 5.  | _____ |
| 2.  | _____ | 6.  | _____ |
| 3.  | _____ | 7. _____                                                                             | _____ |
| 4.  | _____ | 8.  | _____ |

### NOW LET'S DRAW!

Draw these electrical symbols. [But first cover the top of this page.]

- |                                     |  |
|-------------------------------------|--|
| 1. one dry cell                     |  |
| 2. two dry cells connected together |  |
| 3. wire                             |  |
| 4. light bulb                       |  |
| 5. motor                            |  |
| 6. open switch                      |  |
| 7. closed switch                    |  |
| 8. an appliance (resistance)        |  |

### MATCHING Match the two lists. Write the correct letter on the line next to each number.

- |                            |                             |
|----------------------------|-----------------------------|
| 1. _____ flow of electrons | a) where electrons leave    |
| 2. _____ circuit           | b) path for moving electron |
| 3. _____ minus terminal    | c) an electrical device     |
| 4. _____ plus terminal     | d) current electricity      |
| 5. _____ light bulb        | e) where electrons return   |

### TRUE OR FALSE Write T on the line next to the number if the sentence is true. Write F if the sentence is false.

- |                                                                        |
|------------------------------------------------------------------------|
| 1. _____ Current electricity comes from a flow of electrons.           |
| 2. _____ Static electricity lights our homes.                          |
| 3. _____ Most of our electricity comes from generators.                |
| 4. _____ The path that current electricity follows is called a circus. |
| 5. _____ Electrons leave a battery from the plus terminal.             |
| 6. _____ Electrons return to a battery through the plus terminal.      |
| 7. _____ The inside of a battery is filled with zinc.                  |
| 8. _____ Batteries give static electricity.                            |
| 9. _____ Generators make current electricity.                          |
| 10. _____ Electrons stop moving in an incomplete circuit.              |

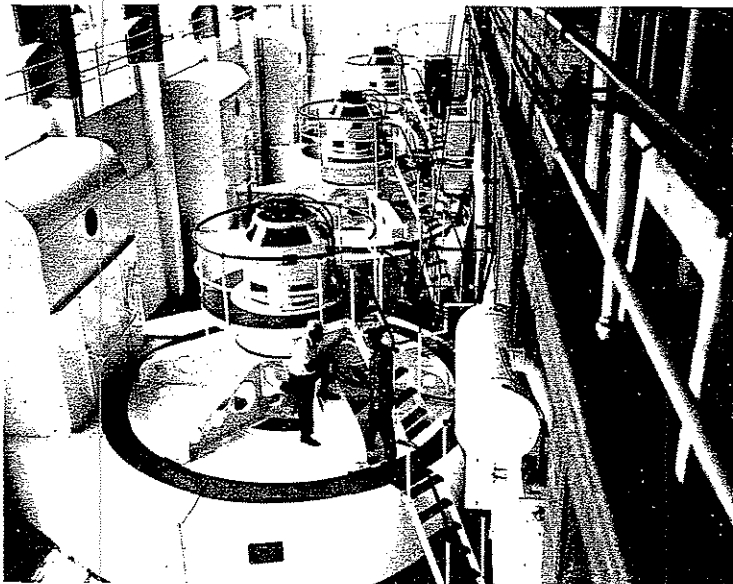
### THROW ONE OUT In each of the following sets of terms, one of the terms does not belong. Circle that term.

- |                        |                     |                        |
|------------------------|---------------------|------------------------|
| 1. current electricity | moving electrons    | static electricity     |
| 2. static electricity  | current electricity | electrons not moving   |
| 3. complete circuit    | incomplete circuit  | bulb lights up         |
| 4. complete circuit    | incomplete circuit  | bulb does not light up |
| 5. bicycle             | flashlight          | electrical device      |

WORD Unscramble each of the following to form a word or term that  
SCRAMBLE you have read in this Aim.

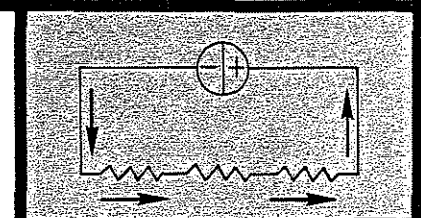
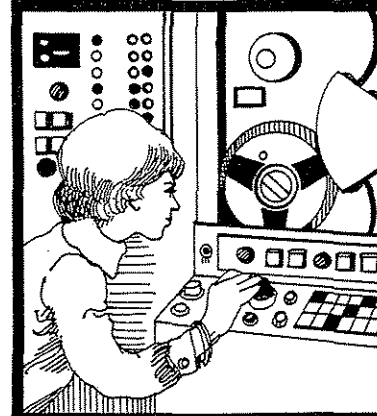
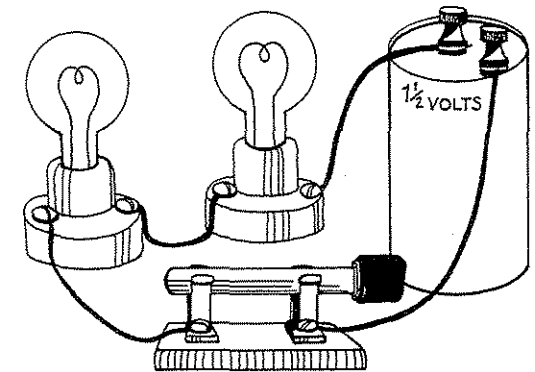
1. NUTRECR \_\_\_\_\_
2. TIRCCUI \_\_\_\_\_
3. TARBETY \_\_\_\_\_
4. REMLATIN \_\_\_\_\_
5. CELOTERN \_\_\_\_\_

REACHING Why don't we get most of our electricity from batteries?  
OUT



## WHAT IS A SERIES CIRCUIT?

3



series circuit: an electrical hook-up in which the current has only one path

## AIM | What is a series circuit?

3

How many light bulbs are there in your home? How many other electrical devices do you have?

Must they all be working if you want to use just one?

Do they all stop working if you shut off just one?

Of course not! Homes are not wired that way. But there are electrical hook-ups that work so that all electrical devices on the circuit are either on or off. This kind of electrical hook-up is called a *series circuit*.

There are two important things to remember about a series circuit:

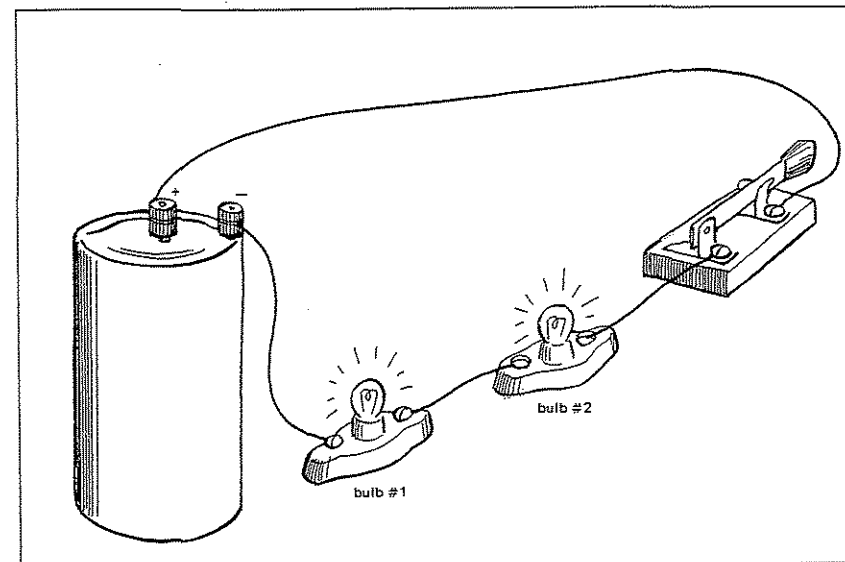
1. *Electrons have only one path to follow* in a series circuit. Each electrical device is connected along this one path. Because of that, the electricity cannot go to just one device. It must move through *all*.

If you turn off any electrical device, you will turn them all off. If you turn that device back on, you will turn on all the devices.

2. The electrical devices, or appliances, share the electrical pressure in a series circuit. If you add electrical appliances, each one gets less electrical pressure. For example, suppose you have light bulbs along a series circuit. Then you add more bulbs. What would happen? Each bulb would give off less light.

Why bother with series circuits? They don't make sense for homes, schools, or factories! But there are special uses for series circuits. Parts of computers, radios, and television sets are wired in series. Parts of space rockets are too!

## A TYPICAL SERIES CONNECTION



1. Trace the path of the electrons in this series circuit. (Draw in arrows along the circuit.)
2. In this circuit, the electricity has \_\_\_\_\_ paths to follow.  
one, two
3. This circuit is \_\_\_\_\_.  
complete, incomplete
4. Where does the electricity have to go before it reaches bulb #2? \_\_\_\_\_
5. If bulb #1 were to go out, bulb #2 would \_\_\_\_\_.  
stay lit, go out
6. If bulb #2 were to go out, bulb #1 would \_\_\_\_\_.  
stay lit, go out
7. In this circuit, each bulb \_\_\_\_\_ getting the full electrical pressure.  
is, is not
8. If more bulbs were added to this circuit, each bulb would give off \_\_\_\_\_ light.  
more, less
9. If this circuit had only one bulb, it would give off \_\_\_\_\_ light.  
more, less

## COMPLETING SENTENCES

Complete the sentences with the choices below.

go off  
less  
one

moving electrons  
series  
share

switched on  
are not

- The circuit you are learning about in this Aim is the \_\_\_\_\_ circuit.
- In a series circuit, electrons have only \_\_\_\_\_ path to follow.
- In a series circuit, when one appliance is shut off, all other appliances \_\_\_\_\_.
- In a series circuit, when one appliance is switched on, all other appliances must be \_\_\_\_\_.
- In a series circuit, the appliances \_\_\_\_\_ the electrical pressure.
- In a series circuit, when you add more appliances, each appliance gets \_\_\_\_\_ power.
- Homes, factories, and schools \_\_\_\_\_ wired in series.
- Current electricity comes from \_\_\_\_\_.

## MATCHING

Match the two lists. Write the correct letter on the line next to each number.

- |                                            |                                        |
|--------------------------------------------|----------------------------------------|
| 1. _____ charged atoms that are not moving | a) only one path for electrons to move |
| 2. _____ moving electrons                  | b) ending point of a circuit           |
| 3. _____ series circuits                   | c) static electricity                  |
| 4. _____ minus terminal                    | d) starting point of a circuit         |
| 5. _____ plus terminal                     | e) current electricity                 |

## WHAT DO THE PICTURES SHOW?

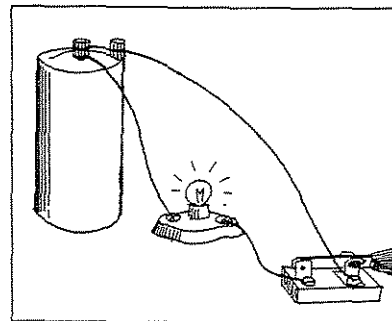
Look at each picture. Then answer the questions.

Quiet! Electrical Engineer at work!

Four series circuits are shown below. Use arrows to show the path of the electricity in each one.

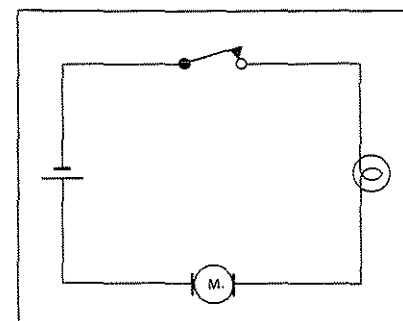
Remember: A series circuit has only one path for the electrons to follow.

A.



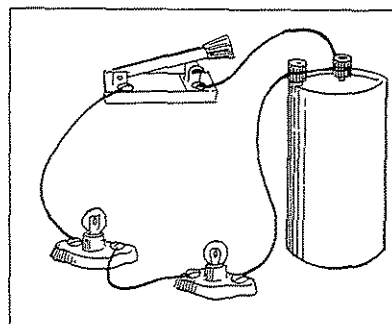
How many paths are there in this circuit? \_\_\_\_\_

B.



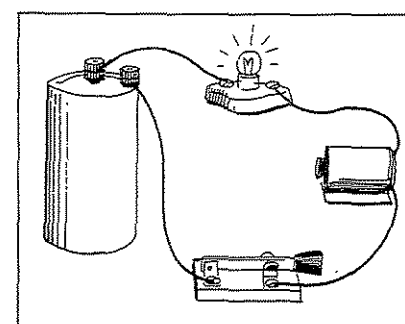
How many paths are there in this circuit? \_\_\_\_\_

C.



How many paths are there in this circuit? \_\_\_\_\_

D.



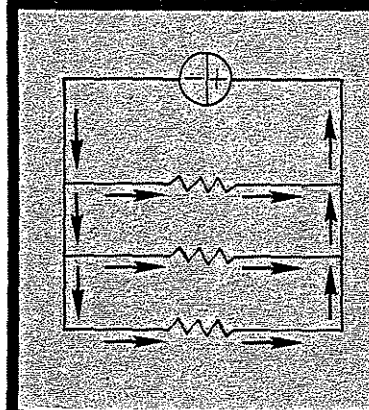
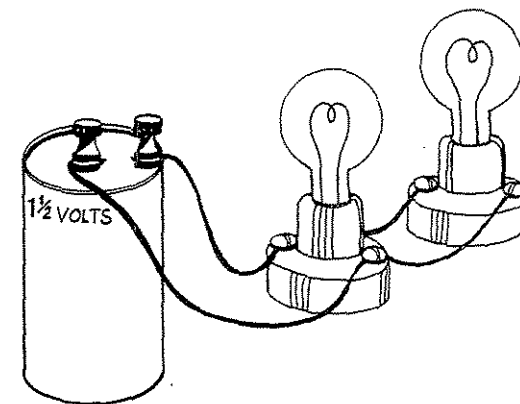
How many paths are there in this circuit? \_\_\_\_\_

COMPLETE THE CHART Use electrical symbols to draw these series circuits.

|                                                                     |  |
|---------------------------------------------------------------------|--|
| 1. one dry cell<br>one open switch<br>two motors                    |  |
| 2. two dry cells<br>one closed switch<br>three light bulbs          |  |
| 3. one dry cell<br>no switch<br>three loads (your choices)          |  |
| 4. two dry cells<br>one open switch<br>one motor<br>two light bulbs |  |

## WHAT IS A PARALLEL CIRCUIT?

4



parallel circuit: an electrical hook-up in which the current has more than one path

## AIM | What is a parallel circuit?

4

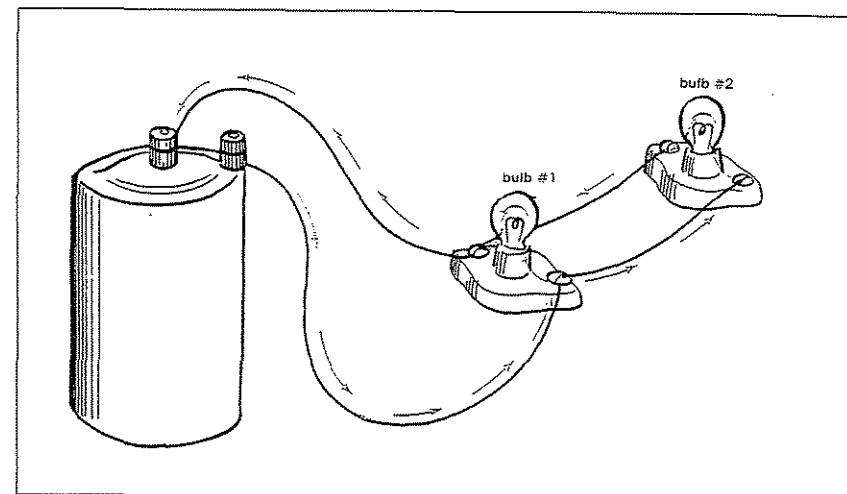
You walk into your home and switch on the TV. You switch on only the TV. You don't have to switch on the toaster and broiler, the hair dryer and radio—You don't have to because your home is not wired in series. Your home is wired in parallel.

There are two important facts you should know about parallel circuits:

1. In a parallel circuit, the electrons have more than one path to follow. Each appliance has its own path. This lets you use or shut off only one appliance at a time.
2. In a parallel circuit, the appliances do not share the electrical pressure. Each appliance gets the full voltage it needs. Adding more loads does not weaken the force. Each load still works with full power. For example, adding more bulbs to a parallel circuit does not make each bulb give off less light.

Parallel circuits make sense for use in homes, schools, and factories.

## A TYPICAL PARALLEL CONNECTION



Look at this diagram. Then answer the questions.

1. How many bulbs are in this parallel circuit? \_\_\_\_\_
2. How many paths does the electricity have to follow? \_\_\_\_\_. Follow the paths that are shown with your pencil.
3. Is this circuit complete or incomplete? \_\_\_\_\_
4. Do the bulbs light up? \_\_\_\_\_
5. Does the electricity have to pass through bulb #1 for bulb #2 to light up? \_\_\_\_\_
6. If bulb #2 were to blow out, bulb #1 would \_\_\_\_\_.  
stay lit, go out
7. If bulb #1 were to blow out, bulb #2 would \_\_\_\_\_.  
stay lit, go out
8. If a third bulb were added, bulbs #1 and #2 would \_\_\_\_\_.  
give off less light, give off the same amount of light
9. The bulbs in this circuit \_\_\_\_\_ share the electrical pressure.  
do, do not
10. Your home is wired \_\_\_\_\_.  
in parallel, in series



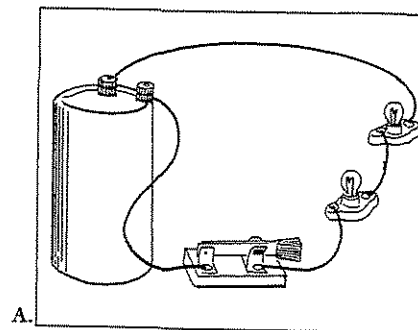
**CHOOSE ONE** Choose the correct word or term for each statement. Write your choice in the space.

- Homes, schools and factories, \_\_\_\_\_ are, are not \_\_\_\_\_ wired in series.
- This school is wired in \_\_\_\_\_ parallel, series \_\_\_\_\_.
- In a series circuit, electricity has \_\_\_\_\_ one, more than one \_\_\_\_\_ path to follow.
- In a parallel circuit, electricity has \_\_\_\_\_ one, more than one \_\_\_\_\_ path to follow.
- In a series circuit, when one bulb goes out, the other bulbs \_\_\_\_\_ stay lit, go off \_\_\_\_\_.
- In a parallel circuit, when one bulb shuts off, the other bulbs \_\_\_\_\_ stay lit, go off \_\_\_\_\_.
- An extra bulb is added to a series circuit. The other bulbs now give off \_\_\_\_\_ less light, the same amount of light \_\_\_\_\_.
- An extra bulb is added to a parallel circuit. The other bulbs now give off \_\_\_\_\_ less light, the same amount of light \_\_\_\_\_.
- In a parallel circuit, you \_\_\_\_\_ can, cannot \_\_\_\_\_ use or shut off one appliance at a time.
- In a series circuit, you \_\_\_\_\_ can, cannot \_\_\_\_\_ use or shut off one appliance at a time.

**MATCHING** Match the two lists. Write the correct letter on the line next to each number.

- |                                                   |                                                    |
|---------------------------------------------------|----------------------------------------------------|
| 1. _____ parallel circuit                         | a) does not change amount of light each bulb gives |
| 2. _____ series circuit                           | b) loads work together                             |
| 3. _____ another bulb added to a parallel circuit | c) loads work one at a time                        |
| 4. _____ another bulb added to a series circuit   | d) does change amount of light each bulb gives     |

**WORKING WITH CIRCUITS** Look at each circuit. Then answer the questions next to it.



A.

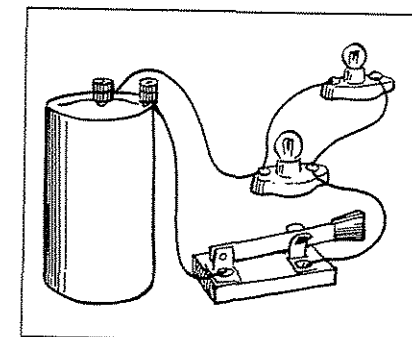
(Note: Do not count a switch as a load.)

- What kind of circuit is this? \_\_\_\_\_
- How many paths do the electrons have to follow? \_\_\_\_\_
- How many loads does this circuit have? \_\_\_\_\_
- Is the circuit complete or incomplete? \_\_\_\_\_
- Are the loads working? \_\_\_\_\_

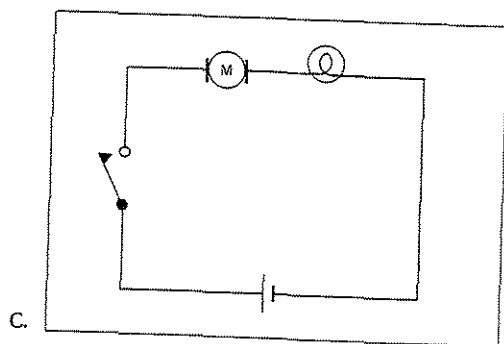
- If one bulb were to blow out, the other bulb would \_\_\_\_\_ stay lit, shut off \_\_\_\_\_.
- Adding another bulb would make the other two give off \_\_\_\_\_ less light, the same amount of light \_\_\_\_\_.
- This \_\_\_\_\_ is, is not \_\_\_\_\_ a good way to wire a home.

B.

- What kind of circuit is this? \_\_\_\_\_
- How many loads does this circuit have? \_\_\_\_\_
- How many paths do the electrons have to follow? \_\_\_\_\_
- Is the circuit complete or incomplete? \_\_\_\_\_



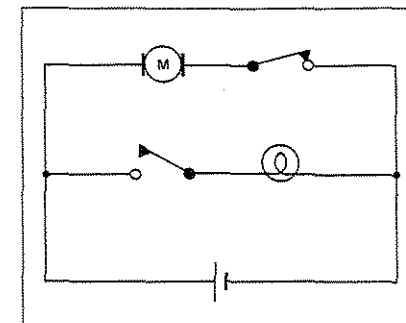
5. Are the loads working? \_\_\_\_\_
6. If one bulb were to go off, the other bulb would give off  
\_\_\_\_\_ more light, the same amount of light
7. Adding another bulb, would make each bulb give off  
\_\_\_\_\_ less light, the same amount of light
8. Is this a good way to wire a home? \_\_\_\_\_



1. What kind of circuit is this? \_\_\_\_\_ parallel, series
2. How many paths do the electrons have to follow? \_\_\_\_\_
3. How many loads does this circuit have? \_\_\_\_\_  
Name them. \_\_\_\_\_
4. Is the circuit complete or incomplete? \_\_\_\_\_
5. Are the loads working? \_\_\_\_\_
6. Is your home wired this way? \_\_\_\_\_

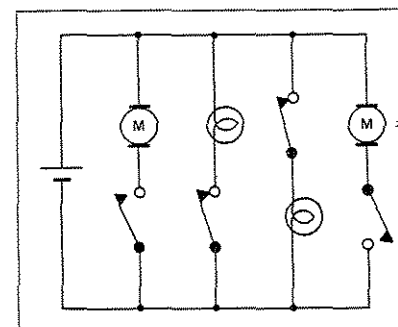
1. What kind of circuit is this?  
\_\_\_\_\_ parallel, series
2. How many paths do the electrons have to follow? \_\_\_\_\_
3. How many loads does this circuit have? \_\_\_\_\_  
Name them. \_\_\_\_\_

D.



4. How many switches does this circuit have? \_\_\_\_\_
5. Which appliance is working? \_\_\_\_\_
6. Which appliance is not working? \_\_\_\_\_
7. Is your home wired this way? \_\_\_\_\_

E.



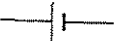
1. What kind of circuit is this?  
\_\_\_\_\_
2. How many paths do the electrons have to follow? \_\_\_\_\_
3. How many loads does this circuit have? \_\_\_\_\_  
Name them. \_\_\_\_\_

4. How many switches does this circuit have? \_\_\_\_\_
5. Which loads are working? \_\_\_\_\_
6. Which loads are not working? \_\_\_\_\_
7. Is your school wired this way? \_\_\_\_\_

**CHECK THE CIRCUIT** Each phrase below describes either a parallel circuit or a series circuit. Which one is it? Put a check (✓) in the proper box.

|                                                                | Parallel Circuit | Series Circuit |
|----------------------------------------------------------------|------------------|----------------|
| 1. only one path for the electricity to follow                 |                  |                |
| 2. more than one path for the electricity to follow            |                  |                |
| 3. loads work or shut off one at a time                        |                  |                |
| 4. all loads are on or all loads are off                       |                  |                |
| 5. appliances share the voltage                                |                  |                |
| 6. appliances do not share the voltage                         |                  |                |
| 7. good way to wire a home                                     |                  |                |
| 8. not a good way to wire homes                                |                  |                |
| 9. an extra bulb makes the others less bright                  |                  |                |
| 10. an extra bulb does not change the brightness of the others |                  |                |

**THROW ONE OUT** In each of the following sets of terms, one of the terms does not belong. Circle that term.

- parallel circuit    loads must work together    wiring in this school
- series circuit    loads must work together    wiring in this school
- electrical symbol            
- switch open    complete circuit    switch closed
- generator    switch    battery

## REVIEWING ELECTRICAL SYMBOLS

Draw the following electrical symbols.

1. open switch

2. closed switch

3. one dry cell

4. two dry cells

5. wire

6. motor

7. light bulb

**TRUE OR FALSE** Write T on the line next to the number if the sentence is true. Write F if the sentence is false.

- \_\_\_\_\_ A dry cell gives static electricity.
- \_\_\_\_\_ Static electricity lights our homes.
- \_\_\_\_\_ Static electricity causes lightning.
- \_\_\_\_\_ A safe place to stay during a lightning storm is under a tree.
- \_\_\_\_\_ Electricity is useful.
- \_\_\_\_\_ Electricity can be dangerous.
- \_\_\_\_\_ This school is wired in parallel.
- \_\_\_\_\_ Your home is wired in series.
- \_\_\_\_\_ A parallel circuit lets you use or shut off one appliance at a time.
- \_\_\_\_\_ Appliances wired in parallel share the electrical pressure.

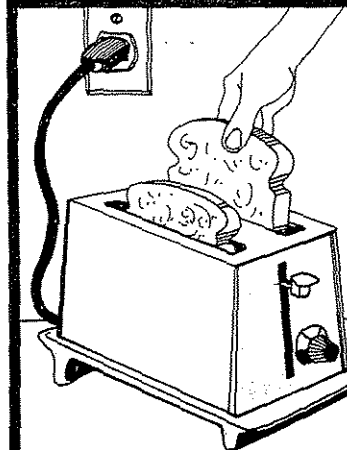
REACHING OUT Draw these circuits. Use electrical symbols.

- |                                                                                                                          |  |
|--------------------------------------------------------------------------------------------------------------------------|--|
| 1. complete series circuit                                                                                               |  |
| <ul style="list-style-type: none"> <li>■ one battery</li> <li>■ one switch</li> <li>■ three bulbs</li> </ul>             |  |
| 2. complete parallel circuit                                                                                             |  |
| <ul style="list-style-type: none"> <li>■ one battery</li> <li>■ one switch</li> <li>■ three motors</li> </ul>            |  |
| 3. incomplete parallel circuit                                                                                           |  |
| <ul style="list-style-type: none"> <li>■ two batteries</li> <li>■ two switches</li> <li>■ one bulb, one motor</li> </ul> |  |



## WHAT IS ELECTRICAL RESISTANCE?

5



resist: to work against

nichrome: a metal that resists electricity very much

molecule: two or more atoms linked up

# AIM | What is electrical 5 | resistance?

Imagine that you are walking against a strong wind. It isn't easy to walk. The wind is slowing you down. It is trying to stop you. We say the wind resists your movement.

Everything that moves meets some kind of resistance. Even electricity meets resistance.

Electric wire resists the flow of electrons. It tries to stop the electrons. The resistance makes the atoms and molecules rub together. This rubbing, or friction, builds heat. The greater the resistance, the greater the heat.

Electrical resistance can be slight—or very great—or in-between. Resistance depends mainly on three things. They are: wire length, wire thickness, and the kind of metal the wire is made of.

**LENGTH OF WIRE** Long wires resist electricity more than short wires do. The longer the wire, the more resistance.

**THICKNESS OF WIRE** Thin wires resist electricity more than thick wires do. The thinner the wire, the greater the resistance.

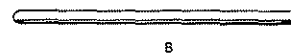
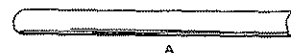
**KIND OF METAL** Some metals resist electricity more than others. Silver resists electricity the least. Copper resists electricity less than most metals. Metals that offer little resistance are good for electrical wiring. Most electrical wiring is made of copper.

Nichrome [NIE krome] is made of nickel and chromium. Nichrome offers great resistance to electricity. Metals that offer great resistance are good for producing heat. They can be used in toasters and electric irons.

## RESISTANCE AND WIRE THICKNESS

Two wires A and B are shown below. They are the same length.

How are they different? \_\_\_\_\_  
 \_\_\_\_\_



Now fill in the blanks below using the letters A and B.

1. Electrons have more room to move along wire \_\_\_\_\_.
2. Electrons have less room to move along wire \_\_\_\_\_.
3. Electrons rub more along wire \_\_\_\_\_.
4. Electrons rub less along wire \_\_\_\_\_.
5. Which wire resists the electrons more? \_\_\_\_\_
6. Which wire resists the electrons less? \_\_\_\_\_
7. There is more friction along wire \_\_\_\_\_.
8. There is less friction along wire \_\_\_\_\_.
9. Which wire stays cooler? \_\_\_\_\_
10. Which wire becomes warmer? \_\_\_\_\_

Conclusion: Thin wire resists electricity \_\_\_\_\_ than thick wire.  
 more less

## RESISTANCE AND WIRE LENGTH

Two wires C and D are shown below. They are both the same thickness.

How are they different? \_\_\_\_\_



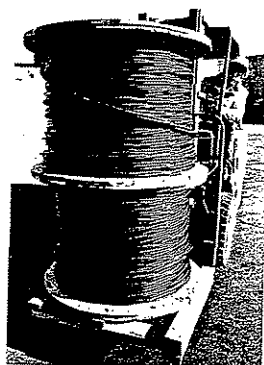
C



D

Now fill in the blanks below, using the letters C and D.

1. Electrons move farther along wire \_\_\_\_\_.
2. Electrons move a shorter distance along wire \_\_\_\_\_.
3. Electrons rub more along wire \_\_\_\_\_.
4. Electrons rub less along wire \_\_\_\_\_.
5. Which wire resists the electrons more? \_\_\_\_\_
6. Which wire resists the electrons less? \_\_\_\_\_
7. There is more friction along wire \_\_\_\_\_.
8. There is less friction along wire \_\_\_\_\_.
9. Which wire stays cooler? \_\_\_\_\_
10. Which wire becomes warmer? \_\_\_\_\_



### CONCLUSION:

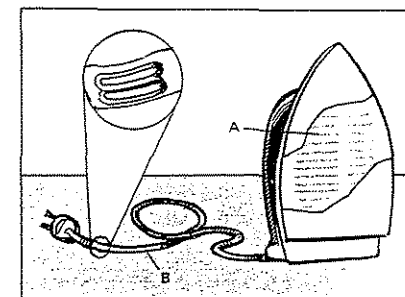
Long wire resists electricity \_\_\_\_\_  
than short wire. more, less

**CHOOSE ONE** Choose the correct word or term for each statement. Write your choice in the space.

1. To "resist" means to \_\_\_\_\_.  
help, try to stop
2. Electrical resistance is caused by \_\_\_\_\_.  
friction, switches
3. Friction comes from \_\_\_\_\_.  
wires, rubbing
4. Friction produces \_\_\_\_\_.  
electrons, heat
5. More friction means \_\_\_\_\_ heat.  
more, less
6. Less friction means \_\_\_\_\_ heat.  
more, less
7. Long wire resists electricity \_\_\_\_\_ than short wire.  
more, less
8. Thick wire resists electricity \_\_\_\_\_ than thin wire.  
more, less
9. Nichrome is a \_\_\_\_\_ resistance wire.  
high, low
10. Copper is a \_\_\_\_\_ resistance wire.  
high, low

### NAME THE WIRE

1. Copper wire is at \_\_\_\_\_.  
A, B
2. Nichrome wire is at \_\_\_\_\_.  
A, B
3. Name the high resistance wire. \_\_\_\_\_
4. Name the low resistance wire. \_\_\_\_\_
5. Which one gets very hot? \_\_\_\_\_
6. Which one gets less hot? \_\_\_\_\_



# KEEPING UP WITH SCIENCE

## ELECTRICITY WITH NO RESISTANCE



In 1911, Dutch physicist H.K. Onnes performed an experiment. He cooled mercury to 452 degrees below zero on the Fahrenheit scale ( $-268.88^{\circ}\text{C}$ ). That's nearly the coldest temperature possible. Onnes then sent an electric current through the supercooled mercury. He discovered that the mercury had lost all its resistance to electrical current. Since that time, scientists have tried to find out why this happens.

We know that all atoms vibrate. We also know that removing heat slows down the vibrations. Physicists have discovered that at extremely low temperatures the vibration speed of supercooled mercury atoms is timed perfectly with passing waves of electrons. Whenever a wave of electrons (electricity) passes a group of slowed-down, supercooled atoms, the vibrating atoms move away from the electrons. In other words, the atoms do not get in the way of the electrons. (It is like jumping rope. The feet miss the rope—the electricity misses the atoms.) When this happens, electrical resistance disappears.

The ability of certain ultracold substances to conduct electricity without re-

sistance is called superconductivity. Until recently, superconductivity was only a scientific curiosity. Scientists believed this property had great potential. But they were unable to find ways of putting it to use until recently.

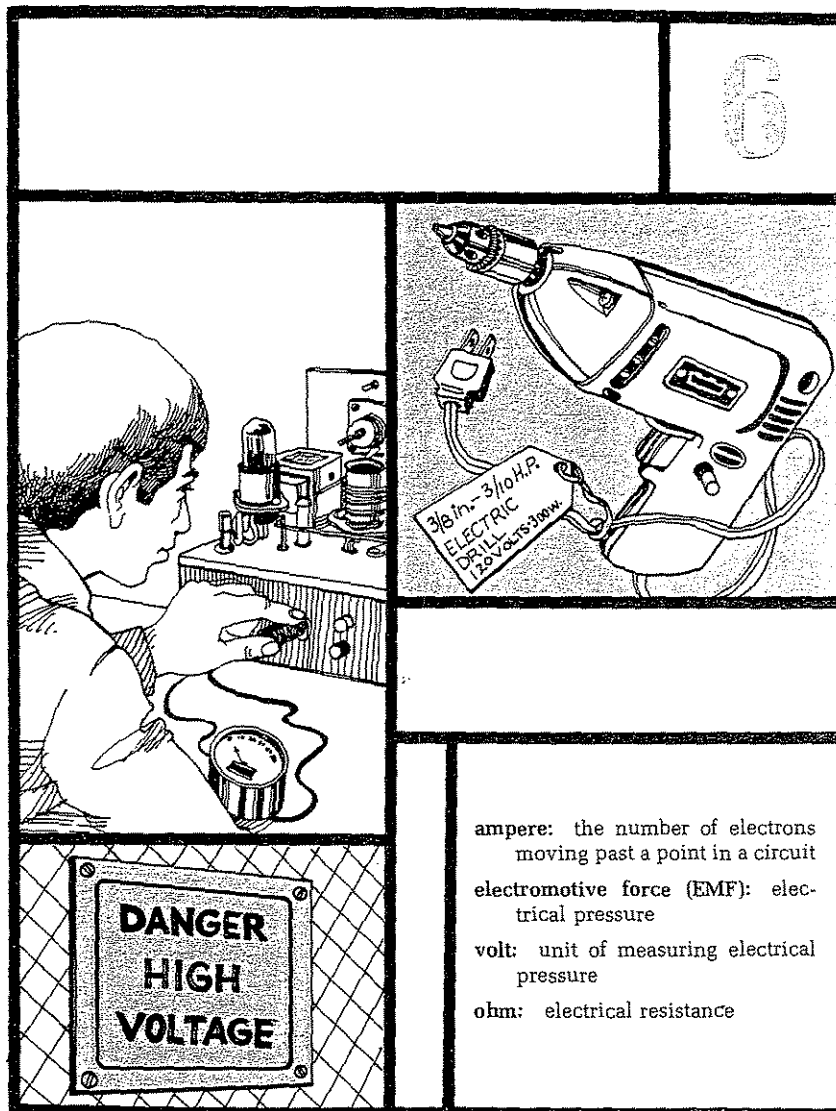
The main problem was to keep the object extremely cold. This is now possible because helium gas becomes a liquid when heat is removed from it. It condenses into a liquid at  $-268.88^{\circ}\text{C}$ ; it does not freeze (become a solid). A constant flow of liquid helium maintains the supercold temperature. Other problems have also been solved. Superconductivity is nearly ready to serve society. But how?

Superconductivity can produce more electrical power with much less fuel. For this reason it can save energy and a great deal of money. A generator with a supercold rotor can produce twice as much electricity as a standard generator twice its size.

The first superconducting generator in the United States is expected to be used by 1986. By the early part of the next century, this new breed of generator will probably produce most of our electricity.

# WHAT ARE AMPERES, VOLTS, AND OHMS?

6



ampere: the number of electrons moving past a point in a circuit  
electromotive force (EMF): electrical pressure  
volt: unit of measuring electrical pressure  
ohm: electrical resistance

## AIM | What are amperes, volts, 6 | and ohms?

How do you measure temperature? In degrees. You measure time in minutes, hours, days, etc. How do you measure length? Weight?

We use different units to measure different things. There are special units to measure electricity too. Three of the most important are ampere, volt, and ohm.

**AMPERE [AM peer]** The size of an electric current depends on how many electrons pass a point in a circuit every second. The greater the number of electrons, the larger the current. Fewer electrons mean a smaller current.

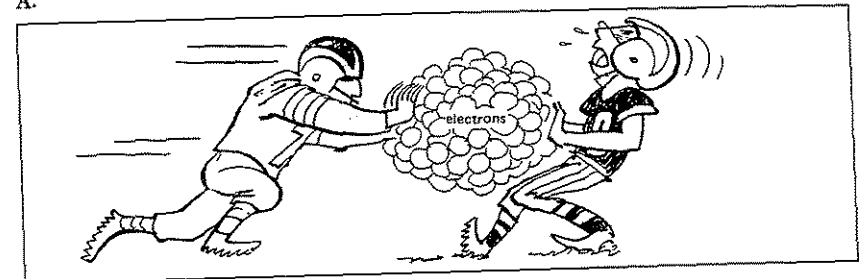
The size of an electric current is measured in amperes [amps]. We can say that "ampere" is another name for electric current.

**VOLT** Nothing moves by itself. A force is needed to make something move. Electricity needs a force to move it. Electrons move in a circuit because a force pushes them. The name for the force or pressure that pushes electrons is *electromotive force*. It is often called EMF. The strength of the EMF is measured in volts.

**OHM [OME]** Ohms measure the resistance to the flow of electrons. You know that a wire resists the flow of electrons. The amount of resistance is measured in ohms.

There is a connection between amps, volts, and ohms. When one changes, there must be a change in one or both of the others. There is a rule for figuring these changes. It is called *Ohm's Law*.

A.



VOLTS

AMPERES (AMPS)

OHMS

The force that moves electrons in a circuit

The number of electrons that are moving

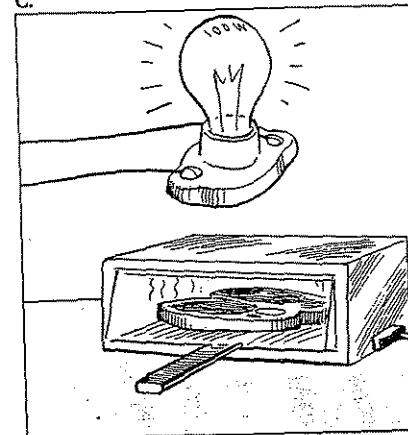
Resistance—the force that tries to stop or slow the electrons

B.

6,281,000,000,000,000,000

This number of electrons passing a point in a wire every second is one ampere of current. Which one is easier to say—one ampere or 6,281,000,000,000,000,000 electrons?

C.



Different electrical devices use different amperes.

- A 100-watt light bulb uses about 1 ampere.
- An electric iron or broiler uses about 10 to 12 amperes.



**FILL-IN QUESTIONS** Fill in the correct answer for each of the following.

1. Another name for electric current is \_\_\_\_\_.
2. Amperes tell us how many \_\_\_\_\_ move past a point in a circuit every second.
3. EMF stands for \_\_\_\_\_.
4. Electrical force or pressure is measured in units called \_\_\_\_\_.
5. Electrical resistance is measured in units called \_\_\_\_\_.

**YOUR OWN WORDS, PLEASE!** Use your own words to tell what each of the following is.

1. EMF \_\_\_\_\_
2. VOLTS \_\_\_\_\_
3. AMPERES \_\_\_\_\_
4. OHMS \_\_\_\_\_

**MATCHING** Match the two lists. Write the correct letter on the line next to each number.

- |                    |                                               |
|--------------------|-----------------------------------------------|
| 1. _____ volts     | a) electrical resistance                      |
| 2. _____ amps      | b) path for moving electrons                  |
| 3. _____ circuit   | c) relationship between volts, amps, and ohms |
| 4. _____ Ohm's Law | d) electrical pressure                        |
| 5. _____ ohms      | e) number of electrons                        |

**TRUE OR FALSE** Write T on the line next to the number if the sentence is true. Write F if the sentence is false.

1. \_\_\_\_\_ EMF stands for a number of electrons.
2. \_\_\_\_\_ Another name for resistance is ampere.
3. \_\_\_\_\_ Volts describe electrical pressure or force.
4. \_\_\_\_\_ Different circuits have different amps, volts, and ohms.
5. \_\_\_\_\_ If volts change, then amps and ohms stay the same.

**WORD SCRAMBLE** Unscramble each of the following to form a word or term that you have read in this Aim.

1. PREAME \_\_\_\_\_
2. SEPRURES \_\_\_\_\_
3. MOH \_\_\_\_\_
4. TOLV \_\_\_\_\_
5. TRENROC \_\_\_\_\_

**LET'S REVIEW** Choose one—Choose the correct word or term for each statement. Write your choice in the space.

1. Electricity that is not moving is called \_\_\_\_\_ electricity.  
static, current
2. Electricity that is moving is called \_\_\_\_\_ electricity.  
static, current
3. Friction produces \_\_\_\_\_ electricity.  
static, current
4. A dry cell produces \_\_\_\_\_ electricity.  
static, current
5. The electricity we use is \_\_\_\_\_ electricity.  
static, current
6. Current electricity is the flow of \_\_\_\_\_.  
atoms, electrons

7. Most current electricity comes from generators, dry cells.
8. The circuit that has only one path to follow is the parallel, series circuit.
9. The circuit that has more than one path to follow is the parallel, series circuit.
10. Homes, schools, and factories are wired in parallel, series.
11. "All appliances on or all off" tells us that the circuit is wired in parallel, series.
12. "Any number of appliances on or off" tells us that the circuit is wired in parallel, series.
13. Change of wire length or thickness does, does not change electrical resistance.
14. Nichrome is a high, low resistance wire.
15. A high resistance wire builds little, much heat.
16. A low resistance wire builds little, much heat.
17. Copper is a high, low resistance wire.
18. The size of an electric current is measured in amperes, volts, ohms.
19. Electrical pressure is measured in amperes, volts, ohms.
20. Electrical resistance is measured in amperes, volts, ohms.

## HOW MUCH FORCE DOES A CIRCUIT NEED?



# AIM 7 | How much force does a circuit need?

How hard do you have to push to move a box along the ground? It depends. How many things are in the box? How rough is the ground?

You have to push harder when there are a lot of things in the box. You have to push harder also, when the ground is rough.

- More force is needed to move more things.
- More force is needed when there is greater resistance.

How much force is needed to move electrons in a circuit? It depends on two things:

- a) how many electrons must be moved.
- b) how much resistance there is.

## NUMBER OF ELECTRONS (AMPS)

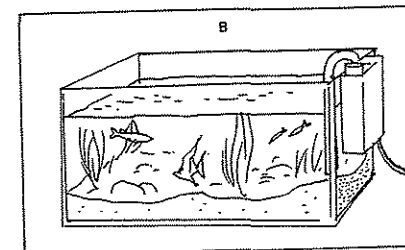
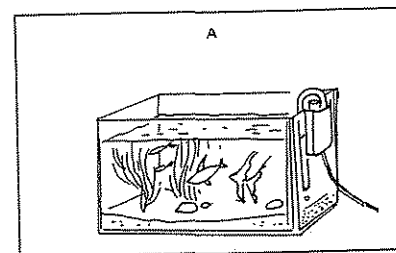
- More force is needed to move more electrons.
- Less force is needed to move fewer electrons.

## RESISTANCE (OHMS) Resistance slows electrons.

- More force is needed when there is more resistance.
- Less force is needed when there is less resistance.

## WHAT DO THE PICTURES SHOW?

Look at the pictures. Then answer the questions. Fill in the blanks. Write A or B in each blank, or choose the correct word.



1. Which tank has the larger pump? \_\_\_\_\_
2. Which tank has the smaller pump? \_\_\_\_\_
3. Which one pumps more water? \_\_\_\_\_
4. Which one pumps less water? \_\_\_\_\_
5. Which pump has more pressure? \_\_\_\_\_
6. Which pump has less pressure? \_\_\_\_\_
7. If something were to get stuck in the pipes,
  - a) the resistance would \_\_\_\_\_  
increase, decrease
  - b) the water pressure would \_\_\_\_\_  
increase, decrease
  - c) \_\_\_\_\_ water would flow.  
More, Less
8. To fight the resistance, you would need \_\_\_\_\_ pressure.  
more, less

## NOW USE THIS THINKING IN WORKING WITH ELECTRICITY!

### CHOOSE ONE

Choose the correct word for each statement. Write your choice in the space.

1. \_\_\_\_\_ force is needed to move more electrons.  
More, Less
2. \_\_\_\_\_ force is needed to move fewer electrons.  
More, Less

3. Another way of saying this is: more amps need more \_\_\_\_\_; fewer  
amps need fewer \_\_\_\_\_.  
ohms, volts                      ohms, volts
4. With greater resistance \_\_\_\_\_ electrons move.  
more, fewer
5. With less resistance \_\_\_\_\_ electrons move.  
more, fewer
6. Another way of saying this is: more ohms means fewer \_\_\_\_\_; fewer  
ohms means more \_\_\_\_\_.  
volts, amps                      volts, amps
7. To fight more resistance, you need \_\_\_\_\_ force.  
more, less
8. Another way of saying this is: more ohms need more \_\_\_\_\_.  
volts, amps

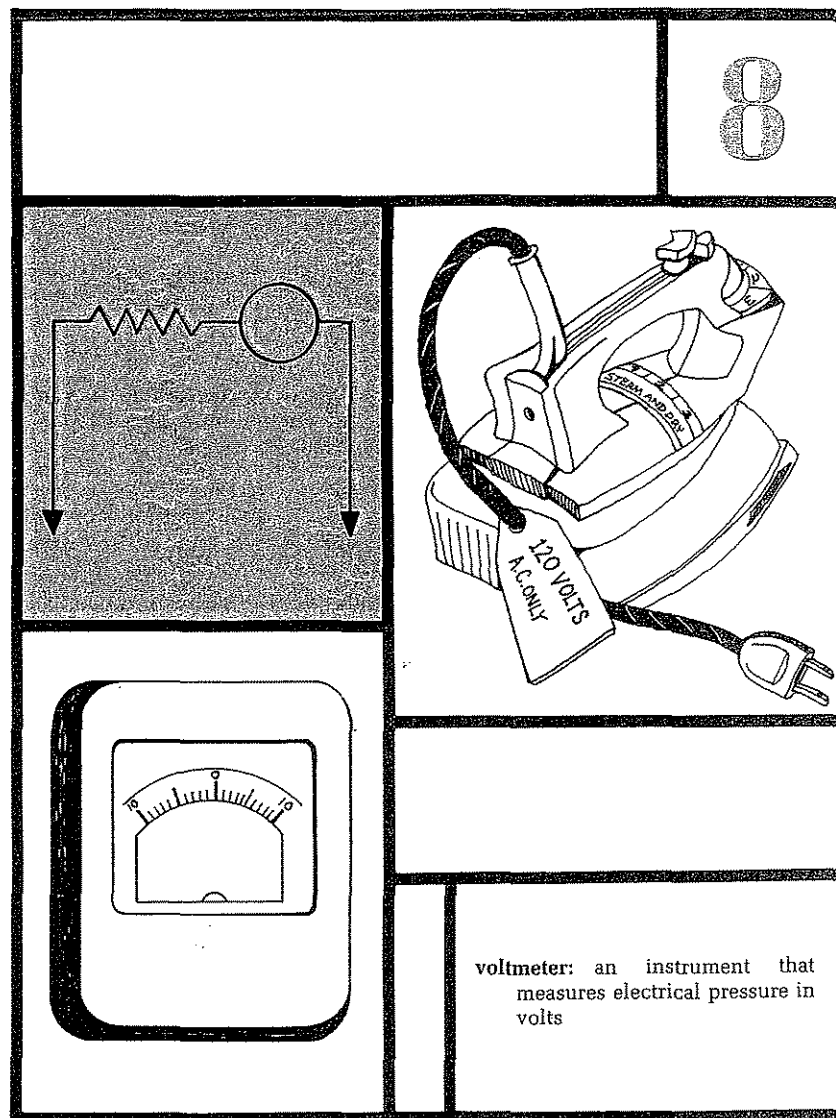
**WORD SEARCH** The words in the list are hidden in the groups of letters. Try to find each word. Draw a line around the word. The spelling may go in any direction: up-and-down, across, or diagonally.

LOAD  
VOLT  
BATTERY  
OHM  
HEAT

|   |   |   |   |   |
|---|---|---|---|---|
| V | A | T | Y | L |
| L | O | A | D | E |
| P | H | L | H | I |
| A | M | Y | T | R |
| B | T | R | H | A |
| A | O | E | A | M |
| L | A | T | D | O |
| T | A | T | H | S |
| L | O | A | L | T |
| E | T | B | O | S |

# HOW DO YOU USE A VOLTMETER?

8



**voltmeter:** an instrument that measures electrical pressure in volts

# AIM | How do you use a

## 8 | voltmeter?

You have many electrical outlets in your home and school. You also have many electrical appliances. Suppose you bought a new appliance. Its tag said that it needs an outlet that supplies about 240 volts. How would you know if your outlet supplied 240 volts?

You could use a *voltmeter*. A voltmeter measures electrical pressure. Electrical pressure or force is measured in volts. For example, the electrical pressure in most homes is about 240 volts.

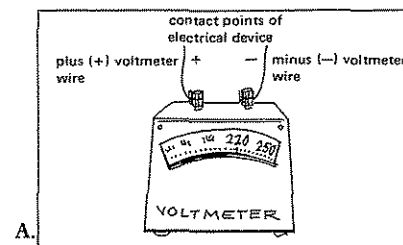
The symbol for a voltmeter is  $\text{V}$ . A voltmeter can measure the full electrical pressure coming from an outlet or a battery. A voltmeter can also measure the pressure an appliance uses.

Here is how you use a voltmeter. [The pictures on the next page will help explain this.]

1. To measure the full electrical pressure from an outlet, just place the voltmeter wires in the socket. Then read the value. [See Figure B.]
2. To measure the full electrical pressure from a dry cell (battery), place the voltmeter's wires on the dry cell's terminals. Read the value. [See Figure C.]
3. To measure the pressure an appliance uses, place the voltmeter wires on the contact points of the appliance. Read the value. [See Figure D.]

Voltmeters come in many sizes. Some voltmeters measure strong voltages. Others measure weak voltages.

## USING A VOLTMETER



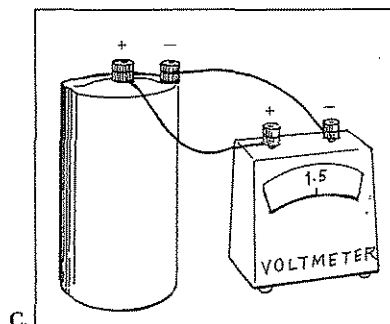
A.

When you connect a voltmeter, you do not unhook any wires. You just put the voltmeter wires on the contact points you want to measure. The voltmeter wires just "straddle" the contact points.



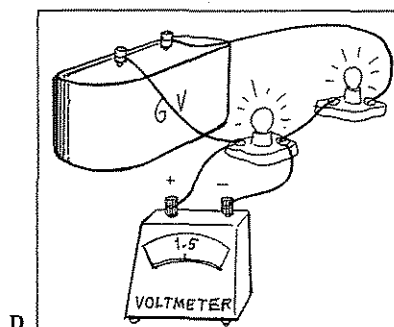
B.

Electricians use a voltmeter to measure voltage at a socket.



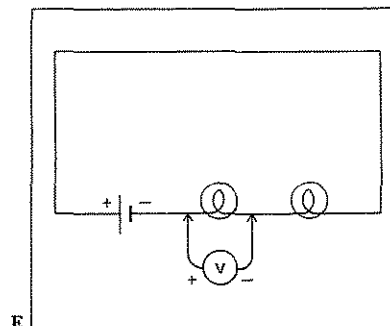
C.

Measuring the voltage of a battery . . .



D.

Measuring the voltage an appliance uses . . . . . →



E.

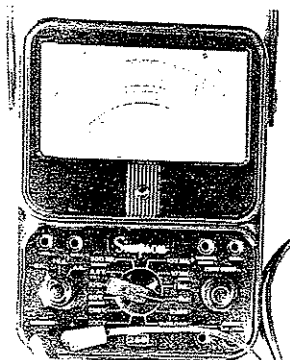
This can be shown in symbol form.

**CHOOSE ONE** Choose the correct word or term for each statement. Write your choice in the space.

- Voltage measures \_\_\_\_\_  
electrical resistance, electrical pressure, number of electrons
- The instrument that measures voltage is called a \_\_\_\_\_  
battery, voltmeter, socket
- When you connect a voltmeter, you \_\_\_\_\_ unhook a wire from the circuit.  
do, do not
- The plus wire of a voltmeter must be connected toward the \_\_\_\_\_ terminal of a battery.  
plus, minus
- The minus wire of a voltmeter must be connected toward the \_\_\_\_\_ end of a socket.  
plus, minus

**MATCHING** Match the two lists. Write the correct letter on the line next to each number.

- |                         |                                          |
|-------------------------|------------------------------------------|
| 1. _____ voltmeter      | a) symbol for voltmeter                  |
| 2. _____ 140            | b) instrument that measures EMF          |
| 3. _____ volt           | c) number of volts from most sockets     |
| 4. _____ plus and minus | d) electrical pressure                   |
| 5. _____ (V)            | e) the two ends of an electrical circuit |



## HOW DO YOU USE AN AMMETER?

9

**ammeter:** an instrument that measures the number of electrons moving in a circuit

# AIM | How do you use an 9 | ammeter?

What is an ammeter [AM meet er]? An ammeter is an instrument that measures electric current in amperes. The symbol for ammeter is  $\text{A}$ .

An ammeter cannot be used the same way as a voltmeter.

An ammeter should never be connected to an outlet or to a dry cell. The ammeter would burn out.

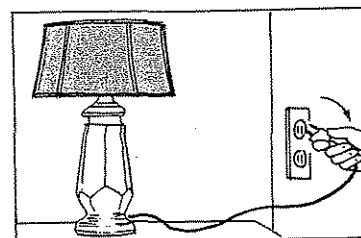
Ammeters are used on electrical appliances. An ammeter is connected right into the circuit. This is what you have to do. [The pictures on the next page will help explain this.]

1. First, unplug the appliance.
2. Then, unhook a wire of the circuit.
3. Next, connect the ammeter wires to the open ends of the appliance wires.
4. Plug in the appliance.
5. Read the value.

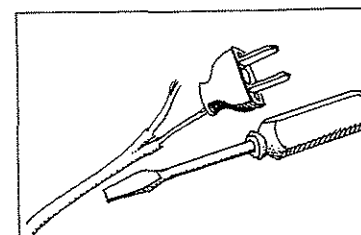
Ammeters come in many sizes. Some ammeters measure small currents. Others measure large currents. It is important to use the right size for the right job.

Electrical instruments damage easily. They should be handled carefully.

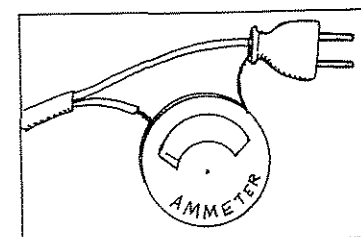
AMMETER Only a teacher or an electrician should do this activity.



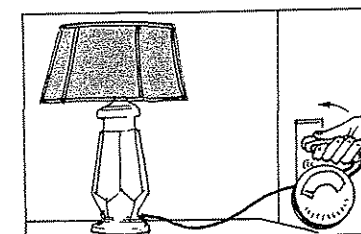
1. Unplug the appliance.



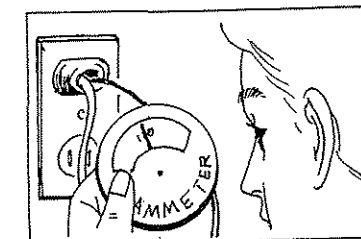
2. Unhook a wire of the circuit.



3. Connect the ammeter wires to the open ends of the appliance wires.

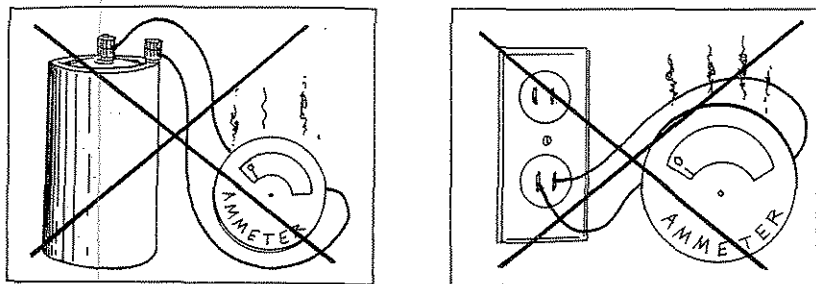


4. Plug in the appliance.



5. Read the value.

## HOOKING UP AN AMMETER



NEVER connect an ammeter to a dry cell or outlet.

**COMPLETING SENTENCES** Complete the sentences with the choices below. One of these may be used twice.

(V)  
amperes  
voltmeter

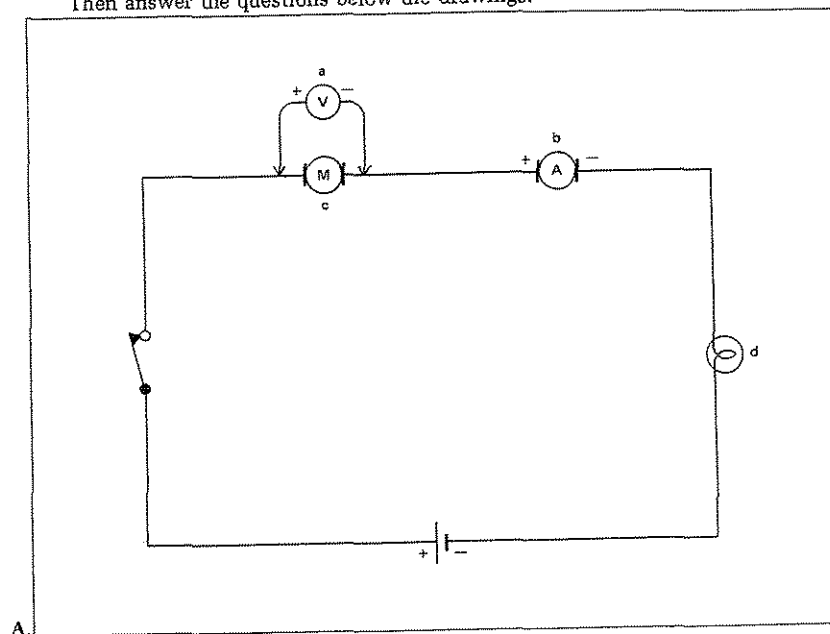
ammeter  
(A)

electric current  
volts

- Electrical pressure is measured in units called \_\_\_\_\_.
- A \_\_\_\_\_ measures electrical pressure.
- The number of electrons in a circuit is measured in units called \_\_\_\_\_ (one word).
- An \_\_\_\_\_ measures the number of electrons moving across a point in a circuit.
- Amperes are a measure of \_\_\_\_\_.
- The symbol for a voltmeter is \_\_\_\_\_.
- The symbol for an ammeter is \_\_\_\_\_.
- The instrument you should never connect to a battery or outlet is the \_\_\_\_\_.

## WORKING WITH CIRCUITS

Study the symbol drawings below.  
Then answer the questions below the drawings.



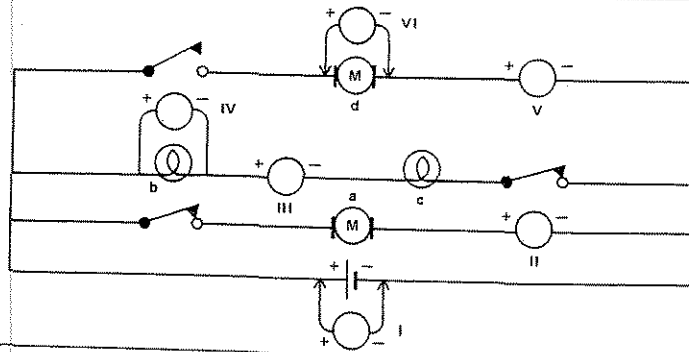
- This is a \_\_\_\_\_ circuit.  
series, parallel
- The circuit is \_\_\_\_\_.  
complete, incomplete
- a) How many appliances are in this circuit? \_\_\_\_\_  
Note: A measuring device is not an appliance.  
b) Name them. \_\_\_\_\_  
\_\_\_\_\_
- Name the measuring instruments in this circuit. \_\_\_\_\_
- The voltmeter is measuring \_\_\_\_\_  
the full voltage, the motor voltage
- The ammeter is measuring \_\_\_\_\_  
electrical pressure, number of electrons
- All electrons must pass through the \_\_\_\_\_  
ammeter, voltmeter



# WHAT IS A MAGNETIC SUBSTANCE?

10

B.

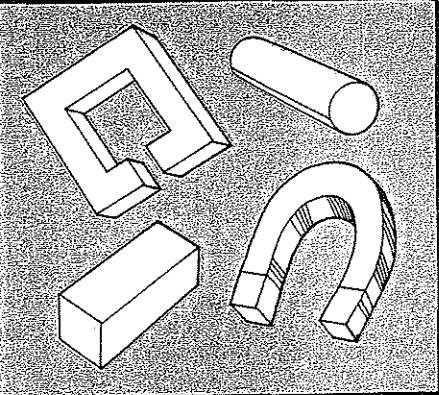
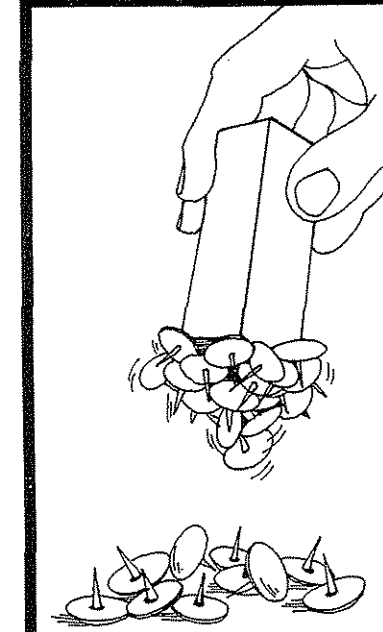


- This is a \_\_\_\_\_ circuit.  
series, parallel
- a) How many appliances are in this circuit? \_\_\_\_\_  
Note: A measuring device is not an appliance.  
b) Name them. a) \_\_\_\_\_ b) \_\_\_\_\_  
c) \_\_\_\_\_ d) \_\_\_\_\_
- The measuring instruments are shown in color and labeled I, II, III, IV, V, and VI.  
a) Which ones are voltmeters? \_\_\_\_\_  
b) Which ones are ammeters? \_\_\_\_\_
- a) Which ones measure electric current? \_\_\_\_\_  
b) Which ones measure electric pressure? \_\_\_\_\_
- Is instrument III measuring the current from appliance b or c? (Remember, electricity flows from minus to plus.) \_\_\_\_\_
- a) Which instruments will show no readings? \_\_\_\_\_  
b) Why? \_\_\_\_\_

## REACHING OUT

A voltmeter measures electrical pressure; an ammeter measures electrical current.

What do you think we call the instrument that measures electrical resistance?



**magnet:** a metal that can attract certain other metals

**lodestone:** a rock that is a magnet

**magnetite:** another name for lodestone

**alloy:** two or more metals melted together

**alnico:** } two alloys that can  
**Permalloy:** } be made into strong magnets

# AIM | What is a magnetic 10 substance?

How do you use magnets? To hold notes on a refrigerator door? To pick up pins or tacks? Did you ever wonder why a magnet works the way it does? A penny won't stick to a refrigerator door. It won't pick up pins or tacks. A magnet will!

What is a magnet? Why does it act the way it does? Why don't other things act like magnets?

Only certain materials can become magnets. A material that can become a magnet is called a *magnetic substance*. A magnetic substance can also be *picked up by a magnet*.

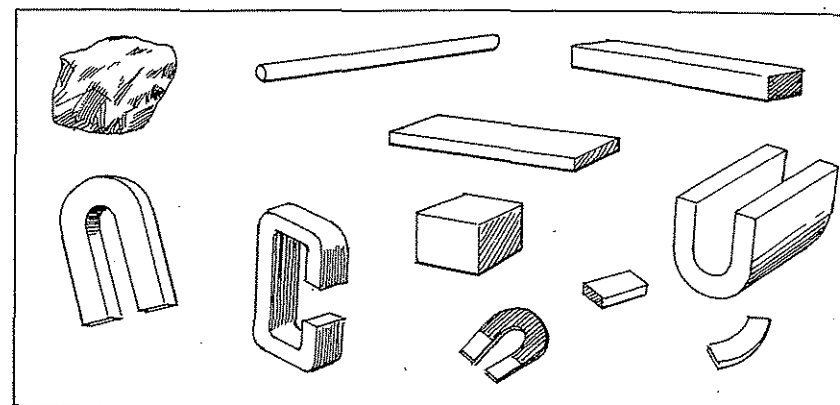
There are only three good magnetic substances. They are the metals *iron*, *nickel*, and *cobalt*. Iron is the most magnetic.

One kind of magnet is found in nature. The rock *magnetite* [MAG nuh tite] is a *natural magnet*. It has bits of iron in it. Magnetite is also called *lodestone*. Most magnets are not natural. They are made by people. Such magnets are called *artificial magnets*.

Most artificial magnets are made of *alloys* [AL oiz]. An alloy is a mixture of metals melted together. Steel is an important alloy. Most magnets are made of steel. Two other alloys are used to make extra-strong magnets. These alloys are *alnico* [AL nick oe] and *Permalloy* [PUR muh loy]. Both alloys contain one or more of the three magnetic substances.

Magnets are made in many sizes, shapes, and strengths. Magnets have many uses.

## MAGNETS



Magnets come in many sizes and shapes.

Magnetic iron (lodestone) was discovered about 2,000 years ago in a part of Asia called *Magnesia*.

The terms *magnet* and *magnetism* come from this place.

**COMPLETING SENTENCES** Complete the sentences with the choices below. One of these may be used twice.

iron  
alloy  
artificial  
magnet  
alnico

magnetite  
picked up  
people  
cobalt

Permalloy  
nickel  
natural  
lodestone

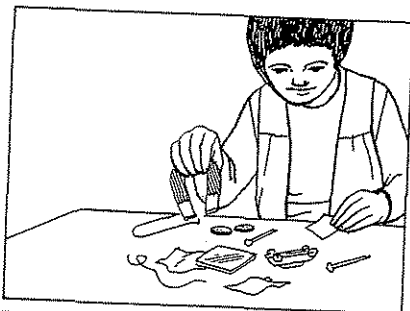
1. A magnetic substance is a substance that can be \_\_\_\_\_ by a magnet.
2. A magnetic substance can also be made into a \_\_\_\_\_.
3. The three good magnetic substances are: \_\_\_\_\_, \_\_\_\_\_, and \_\_\_\_\_.
4. The metal found in most magnets is \_\_\_\_\_.
5. Magnets that are found in nature are called \_\_\_\_\_ magnets.

6. The name of a natural magnet is \_\_\_\_\_. It is also called \_\_\_\_\_.
7. The opposite of natural is \_\_\_\_\_.
8. Most magnets are made by \_\_\_\_\_.
9. A mixture of metals melted together is called an \_\_\_\_\_.
10. Very powerful magnets are made of the alloys \_\_\_\_\_ and \_\_\_\_\_.

### TESTING FOR MAGNETIC SUBSTANCES

Touch each substance listed below with a magnet. See if it is magnetic or nonmagnetic. Put a check [✓] in the proper box.

The last two lines have been left blank. Select two materials not on the list. Test them and write the results on lines 9 and 10.



|                          | Magnetic | Nonmagnetic |
|--------------------------|----------|-------------|
| 1. glass                 |          |             |
| 2. iron nail             |          |             |
| 3. paper                 |          |             |
| 4. plastic               |          |             |
| 5. nickel (not a coin)   |          |             |
| 6. copper                |          |             |
| 7. cobalt                |          |             |
| 8. steel (not stainless) |          |             |
| 9.                       |          |             |
| 10.                      |          |             |

TRUE OR FALSE Write T on the line next to the number if the sentence is true.  
Write F if the sentence is false.

1. \_\_\_\_\_ A magnet is never found in nature.
2. \_\_\_\_\_ All magnets are found in nature.
3. \_\_\_\_\_ Lodestone is a natural magnet.
4. \_\_\_\_\_ Iron is a magnetic substance.
5. \_\_\_\_\_ Iron is an alloy.
6. \_\_\_\_\_ Steel is an alloy.
7. \_\_\_\_\_ Most magnets are made of steel.
8. \_\_\_\_\_ The strongest magnets are made of steel.
9. \_\_\_\_\_ Copper is a magnetic substance.
10. \_\_\_\_\_ Most substances are magnetic.

MATCHING Match the two lists. Write the correct letter on the line next to each number.

- |                               |                                                    |
|-------------------------------|----------------------------------------------------|
| 1. _____ iron, nickel, cobalt | a) mixture of metals                               |
| 2. _____ magnetite            | b) means "not natural"                             |
| 3. _____ alloy                | c) good magnetic metals                            |
| 4. _____ artificial           | d) alloys used for extra-strong artificial magnets |
| 5. _____ alnico and Permalloy | e) natural magnet                                  |

**WORD SCRAMBLE** Unscramble each of the following to form a word or term that you have read in this Aim.

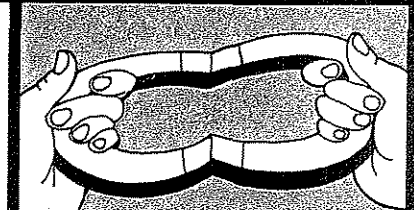
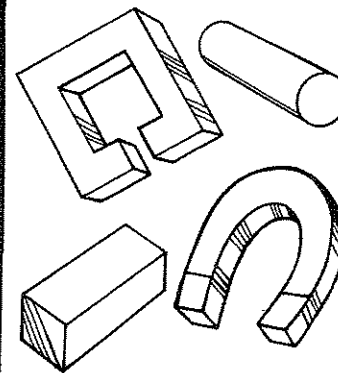
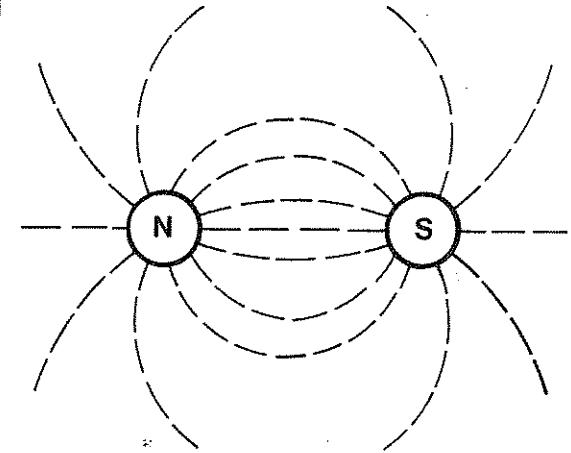
1. BLATCO
2. GETMAN
3. LETNODEOS
4. YOLAL
5. CAINOL

**REACHING OUT** You can buy strips of "magnetic" rubber and plastic.

1. Is plastic rubber or plastic really magnetic? \_\_\_\_\_
2. How is plastic and rubber made to stick like a magnet? \_\_\_\_\_

## HOW DO MAGNETS BEHAVE?

11



**magnetic field:** the space around a magnet where the power of the magnet is felt

**lines of force:** invisible lines of magnetic power

# AIM | How do magnets behave?

11

What are the different shapes magnets come in? Have you seen horseshoe-shaped magnets? bar-shaped magnets? No matter what shape a magnet comes in it has two ends—no more and no less than two. Every magnet has two ends.

The ends of a magnet are called *poles*. One pole is the *north pole*. The other is the *south pole*. A magnet gives off energy. You cannot see the energy. It is strongest at the poles. The energy is weakest in the middle.

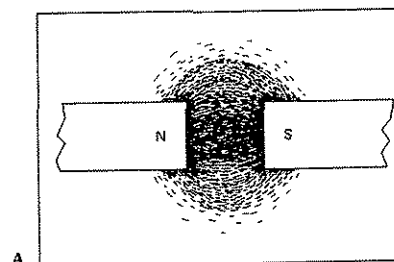
If you hold two magnets together, what happens? The answer depends on the poles! If you hold two north poles together, they push apart. The same will happen with two south poles—they push apart. Two north poles are alike—they are *like poles*. Two south poles are also like poles. *Like poles repel*.

What happens if you hold a north and south pole together? They pull together. A north pole and a south pole are not alike—they are *unlike poles*. *Unlike poles attract*.

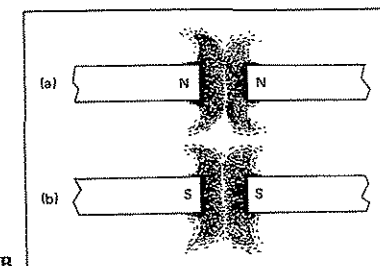
Magnetic energy spreads out in all directions. The energy is made up of many *lines of force*. You cannot see them. All the lines of force make up what is called a *magnetic field*.

A magnet's power is felt within its magnetic field. The field is strongest close to the magnet. The magnetic field grows weaker the farther you get from the magnet.

## WHAT DO THE PICTURES SHOW?

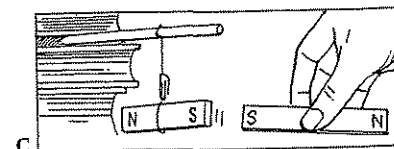


A. Magnetic field between unlike poles.

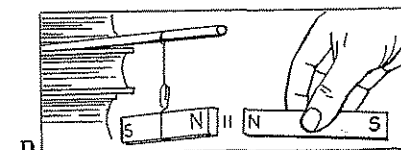


B. Magnetic field between like poles.

Look at each picture. Then answer the questions.



C.

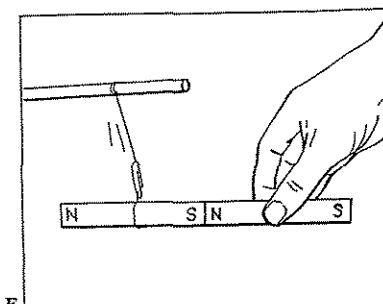


D.

1. a) The hand in Figure C is holding the south pole close to the \_\_\_\_\_ pole of the hanging magnet.  
north, south
- b) They are \_\_\_\_\_ poles.  
like, unlike
- c) The poles \_\_\_\_\_.  
attract, repel

2. a) The hand in Figure D is holding the north pole close to the \_\_\_\_\_ pole of the hanging magnet.  
north, south
- b) They are \_\_\_\_\_ poles.  
like, unlike
- c) The poles \_\_\_\_\_.  
attract, repel

3. CONCLUSION: Like poles \_\_\_\_\_.  
attract, repel



E.

4. a) The hand in Figure E is holding the north pole close to the \_\_\_\_\_ pole of the hanging magnet.  
north, south
  - b) They are \_\_\_\_\_ poles.  
like, unlike
  - c) The poles \_\_\_\_\_.  
attract, repel
5. CONCLUSION: Unlike poles \_\_\_\_\_.  
attract, repel

## HOW TO MAKE A "MAP" OF A MAGNETIC FIELD

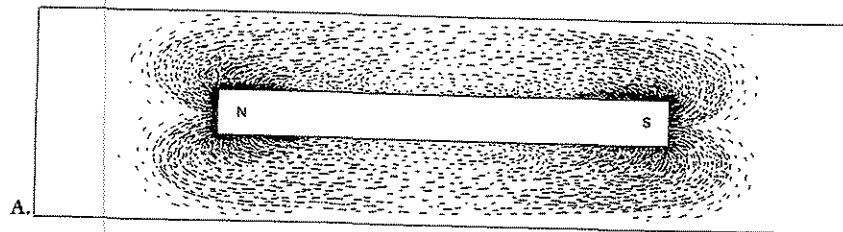
### What You Need

bar magnet  
thin sheet of paper  
iron filings



### How To Do The Experiment

1. Place the magnet on a table.
2. Cover the magnet with the paper.
3. Gently sprinkle the iron filings on the paper.



### What You Learned

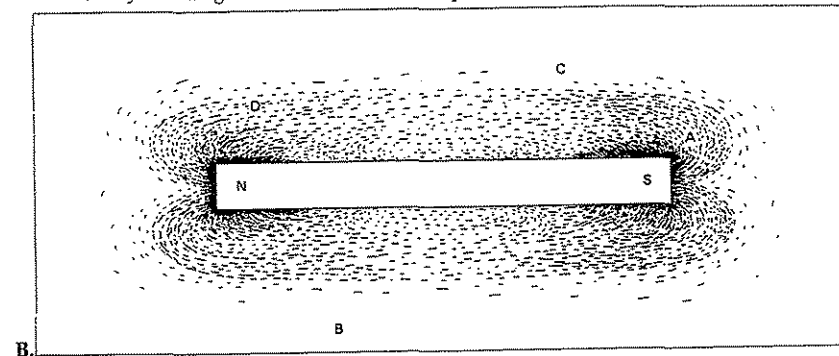
Your "map" should look something like this. Study the "map." Then answer these questions.

1. Most of the iron filings are at \_\_\_\_\_  
the poles, the middle
2. There are fewer iron filings at \_\_\_\_\_  
the poles, the middle
3. A magnet is strongest at \_\_\_\_\_  
the poles, the middle
4. A magnet is weakest at \_\_\_\_\_  
the poles, the middle
5. Most iron filings are \_\_\_\_\_ the magnet.  
close to, far from
6. As you move away from the magnet, there are \_\_\_\_\_ iron filings.  
more, fewer
7. A magnetic field is strongest \_\_\_\_\_ a magnet.  
close to, far from
8. As you move away from a magnet, the magnetic field becomes \_\_\_\_\_  
stronger, weaker

## WORKING WITH MAGNETIC FIELDS

The diagram below shows a bar magnet and its magnetic field. A, B, C, and D are pieces of iron.

Study the diagram. Then answer the questions.

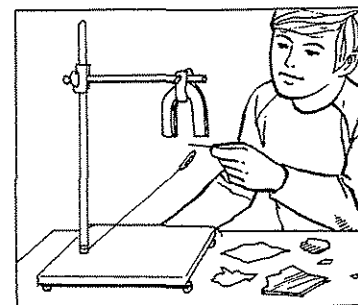


1. Which pieces of iron are outside the magnetic field? \_\_\_\_\_
2. Which pieces of iron are inside the magnetic field? \_\_\_\_\_
3. Look at the pieces that are inside the magnetic field.
  - a) Which one does the magnet attract *more*? \_\_\_\_\_
  - b) Which one does the magnet attract *less*? \_\_\_\_\_

## EXPERIMENT WITH MAGNETISM

Aim: To find out which substances let magnetic energy pass through them and which substances do not.

### What You Need



magnet  
stand with clamp  
thin string  
steel paper clip  
thin pieces of materials listed on the next page

How To Do The Experiment Set up the materials as shown on page 69.

Then, one at a time, hold the materials listed below between the clip and the magnet. Notice what happens. Does the paper clip drop?

Fill in the chart.

| Material   | Does the paper clip drop?<br>[Yes or No] |
|------------|------------------------------------------|
| 1. paper   |                                          |
| 2. cloth   |                                          |
| 3. iron    |                                          |
| 4. cobalt  |                                          |
| 5. glass   |                                          |
| 6. plastic |                                          |
| 7. nickel  |                                          |

What You Learned

- Which materials did not make the paper clip drop? \_\_\_\_\_
- Paper, cloth, glass, and plastic are \_\_\_\_\_ substances.  
magnetic, non-magnetic
  - Magnetic energy \_\_\_\_\_ go through these substances.  
does, does not
- Magnetic energy \_\_\_\_\_ pass through non-magnetic substances.  
does, does not
- Which materials did make the paper clip drop? \_\_\_\_\_
- Iron, nickel, and cobalt are \_\_\_\_\_ substances.  
magnetic, non-magnetic
  - Magnetic energy \_\_\_\_\_ go through these substances.  
does, does not
- Magnetic energy \_\_\_\_\_ go through magnetic substances.  
does, does not

Conclusion

- \_\_\_\_\_ substances do not affect a magnetic field.  
Magnetic, Non-magnetic
- \_\_\_\_\_ substances do affect a magnetic field.  
Magnetic, Non-magnetic

COMPLETING SENTENCES Complete the sentences with the choices below. Three of these may be used twice.

|                |            |
|----------------|------------|
| unlike poles   | south pole |
| like poles     | poles      |
| repel          | attract    |
| magnetic field | north pole |

- The ends of a magnet are called \_\_\_\_\_.  
(one word)
- One end of a magnet is called the \_\_\_\_\_; the other end is called the \_\_\_\_\_.
- A south pole and south pole, or a north pole and north pole are called \_\_\_\_\_.
- A north pole and south pole are called \_\_\_\_\_.
- Like poles \_\_\_\_\_.
- Unlike poles \_\_\_\_\_.
- Two north poles or two south poles will \_\_\_\_\_.
- A north pole and a south pole will \_\_\_\_\_.
- The space around a magnet where the power of a magnet is felt is called its \_\_\_\_\_.
- A magnet is strongest at the \_\_\_\_\_.

MATCHING Match the two lists. Write the correct letter on the line next to each number.

- |                               |                           |
|-------------------------------|---------------------------|
| 1. _____ like poles           | a) make up magnetic field |
| 2. _____ unlike poles         | b) magnetic substances    |
| 3. _____ lines of force       | c) repel                  |
| 4. _____ center of a magnet   | d) attract                |
| 5. _____ iron, nickel, cobalt | e) weakest part           |

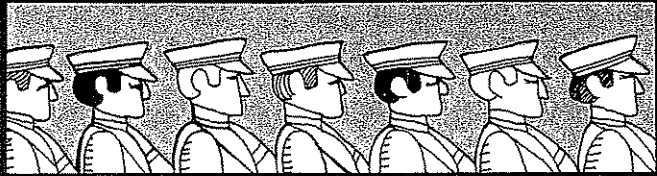
TRUE OR FALSE Write T on the line next to the number if the sentence is true.  
Write F if the sentence is false.

1. \_\_\_\_\_ A north pole and a north pole are like poles.
2. \_\_\_\_\_ Two north poles are the only like poles.
3. \_\_\_\_\_ Like poles attract.
4. \_\_\_\_\_ A north pole and a south pole are unlike poles.
5. \_\_\_\_\_ Unlike poles repel.
6. \_\_\_\_\_ Lines of force are invisible.
7. \_\_\_\_\_ A magnet is strongest at the middle.
8. \_\_\_\_\_ Glass and paper let magnetic energy pass through them.
9. \_\_\_\_\_ Glass and paper are magnetic substances.
10. \_\_\_\_\_ Iron lets magnetic energy pass through it.
11. \_\_\_\_\_ Iron is a magnetic substance.

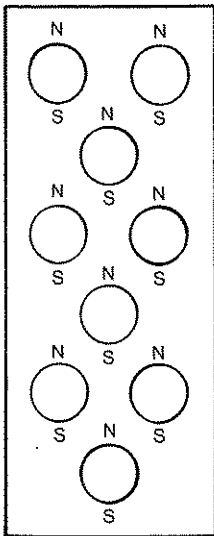
THROW ONE OUT In each of the following set of terms, one of the terms does not belong. Circle that term.

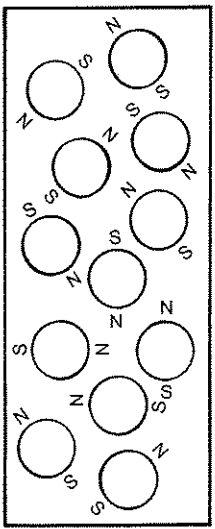
1. magnetic substance    glass    iron
2. natural magnet    cobalt    lodestone
3. aluminum    iron    cobalt
4. alloy    nickel    alnico
5. artificial    factory-made    nature-made

# WHAT CHANGES TAKE PLACE WHEN A SUBSTANCE BECOMES A MAGNET?



12





domain: a group of lined-up atoms



# AIM | What changes take place 12 | when a substance becomes a magnet?

Soldiers are standing around in no set order. The captain shouts, "ATTENTION!" The soldiers line up in neat rows. They are ready to act together.

Something like that happens when a substance is magnetized. An atom is the smallest part of a substance. Every atom has a north pole and a south pole. When the substance is not a magnet, the atoms face in many directions. They are not lined up. The magnetic forces of the different atoms work against one another. Their magnetic power is not felt.

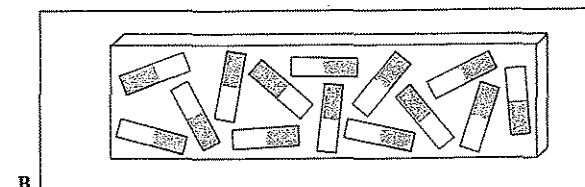
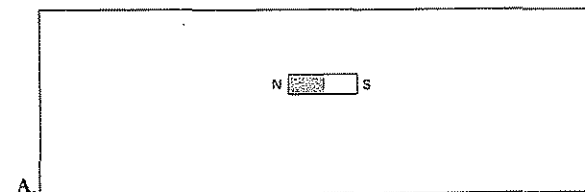
When a substance becomes a magnet, many atoms group together. Each group acts like a magnet. All the north poles face one way. All the south poles face the opposite way. The magnetic power is felt because the atoms work together. The whole piece becomes a magnet.

A group of lined-up atoms is called a domain [doe MAIN]. A magnet has millions of domains. If a magnet breaks, each piece still has domains. Each piece is a magnet. The smallest piece of a magnet is just one domain.

Only atoms of iron, nickel, and cobalt can form domains. They are the only magnetic substances. All magnetic alloys contain iron, nickel or cobalt.

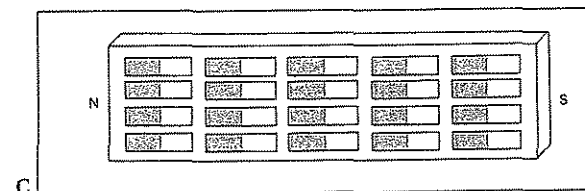
## WHAT DO THE PICTURES SHOW?

Look at each picture. Then answer the questions.



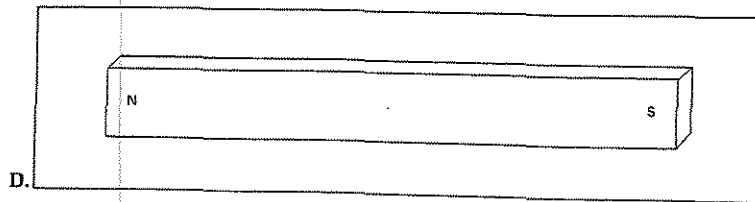
Single atoms in a piece of iron that is not a magnet.

1. The poles face \_\_\_\_\_ in one direction. in many directions
2. The magnetic forces \_\_\_\_\_ work together. work against each other
3. The iron's magnetic power \_\_\_\_\_ is. is not felt.

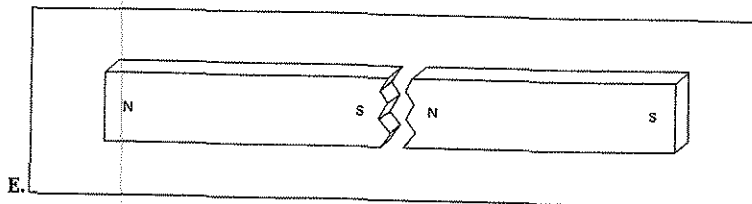


Groups of atoms in a piece of iron that is a magnet.

4. What are these groups of atoms called? \_\_\_\_\_
5. Their poles face \_\_\_\_\_ in only one direction. in many directions
6. The magnetic forces \_\_\_\_\_ work together. work against each other
7. The iron's magnetic power \_\_\_\_\_ is. is not felt.

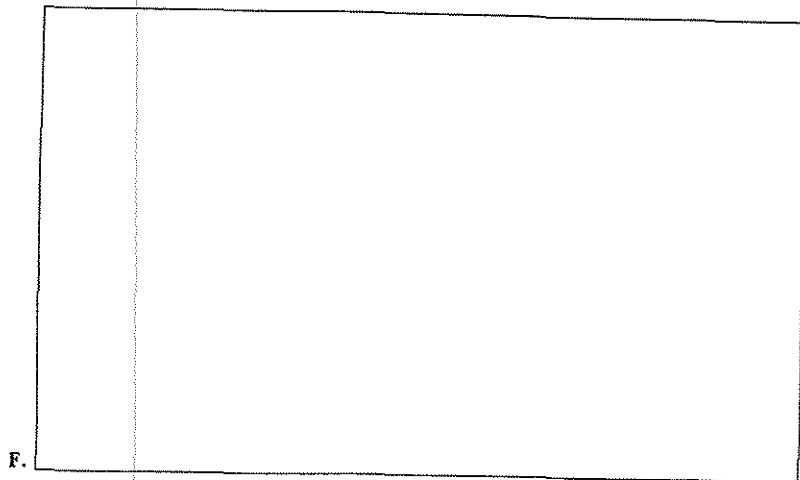


This is a bar magnet.



This is the same bar magnet broken in half.

8. Does breaking a magnet destroy the magnet? \_\_\_\_\_
9. How would four pieces look? Draw the picture in the box below. Label the poles.



10. How many magnets do you have now? \_\_\_\_\_
11. What is the smallest part of any magnet? \_\_\_\_\_

# COMPLETING SENTENCES Complete the sentences with the choices below.

work together  
magnet  
one direction

domains  
in all directions

one domain  
ten

- Every atom of a magnetic substance is like a tiny \_\_\_\_\_.
- The atoms of matter that is not a magnet face \_\_\_\_\_.
- The atoms of a magnet form groups called \_\_\_\_\_.
- The poles of domains line up in \_\_\_\_\_.
- The magnetic powers of domains \_\_\_\_\_.
- The smallest part of a magnet is \_\_\_\_\_.
- If you break a magnet into ten pieces, you end up with \_\_\_\_\_ magnets.

TRUE OR FALSE Write T on the line next to the number if the sentence is true.  
Write F if the sentence is false.

- \_\_\_\_\_ Wood is a magnetic substance.
- \_\_\_\_\_ Iron is a magnetic substance.
- \_\_\_\_\_ Every piece of iron has domains.
- \_\_\_\_\_ Magnetized iron has domains.
- \_\_\_\_\_ Only magnets have domains.
- \_\_\_\_\_ Domains work against each other.
- \_\_\_\_\_ A domain is larger than an atom.
- \_\_\_\_\_ A magnet has only two poles.
- \_\_\_\_\_ A magnet can have two north poles.
- \_\_\_\_\_ You can destroy a magnet by breaking it.

**CHOOSE ONE** Choose the correct word or term for each statement. Write your choice in the space.

1. Atoms normally \_\_\_\_\_ lined up.  
are, are not
2. You have a piece of iron that is not a magnet. The atoms \_\_\_\_\_ lined up.  
are, are not
3. The atoms of iron \_\_\_\_\_ be made to line up.  
can, cannot
4. A substance with lined-up atoms is called \_\_\_\_\_.  
an alloy, a magnet
5. A group of lined-up atoms is called a \_\_\_\_\_.  
magnetic field, domain
6. Substances like wood, glass, and plastic \_\_\_\_\_ form domains.  
do, do not
7. Iron, nickel, and cobalt \_\_\_\_\_ form domains.  
do, do not

**WORD SCRAMBLE** Unscramble each of the following to form a word or term that you have read in this Aim.

1. MOANID
2. LICKEN
3. MOAT
4. POURG
5. RONI

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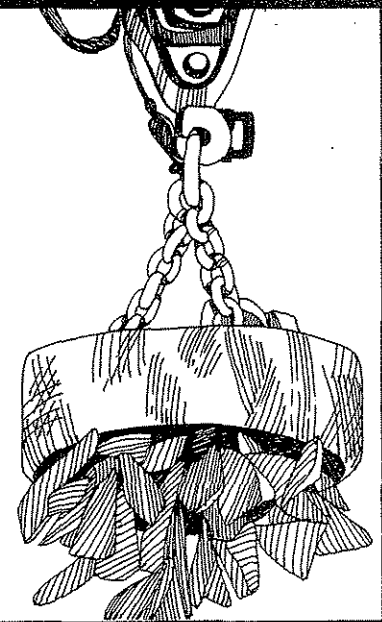
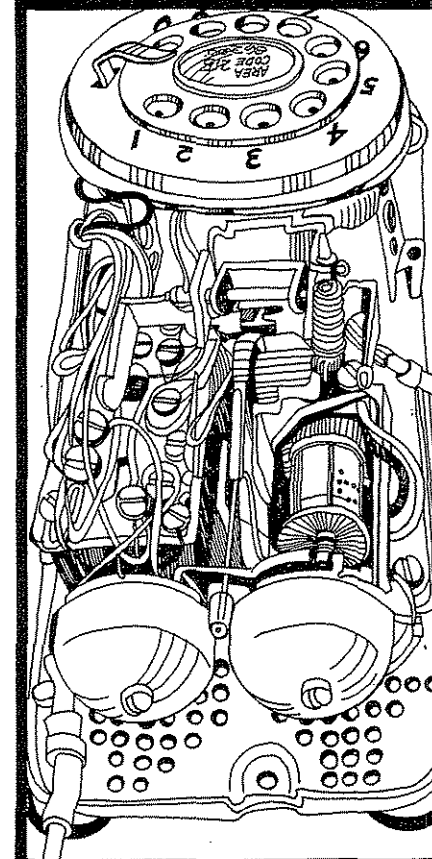
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# WHAT ARE TEMPORARY AND PERMANENT MAGNETS?

13



**permanent:** lasting for a very long time  
**temporary:** lasting for only a short time

# AIM | What are temporary and permanent magnets?

## 13 | permanent magnets?

You probably know the word *temporary* [TEM puh reh ree]. Maybe you know someone who had a temporary job. It lasted for a short time—a week, a month, a summer. The opposite of temporary is *permanent* [PUR muh nent]. A permanent job lasts for a very long time—years and years.

Something that lasts a short time is temporary. Something that lasts a very long time is permanent. Things that are permanent seem to last forever.

Some magnets are temporary magnets. Others are permanent magnets.

### TEMPORARY MAGNETS

Temporary magnets keep their magnetism for only a short time. Then they lose the magnetism.

Most temporary magnets are made of soft iron. Soft iron becomes a magnet very easily. But soft iron loses its magnetism easily.

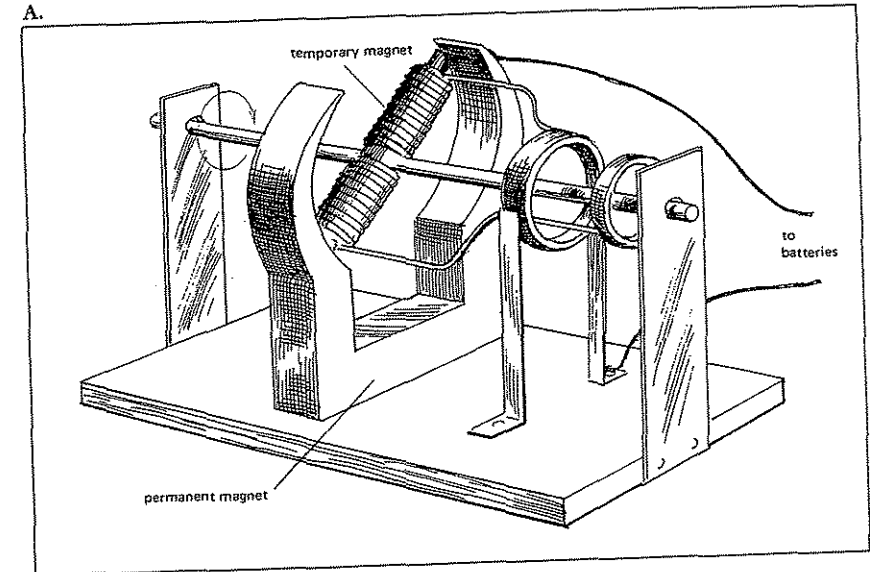
### PERMANENT MAGNETS

Permanent magnets keep their magnetism. They can be used over and over again. The magnets you use in class are permanent magnets. So are the magnets in your home.

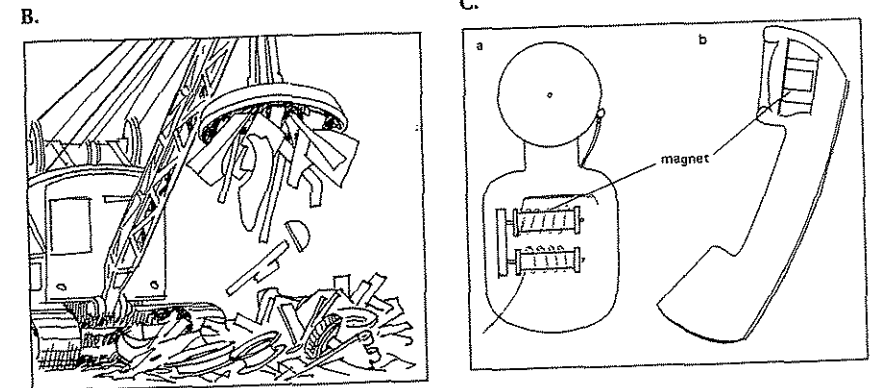
Most permanent magnets are made of steel. Steel does not become a magnet as easily as iron does. But once steel becomes a magnet, it keeps its magnetism.

There are extra-strong permanent magnets. They are made of alnico and Permalloy.

## TEMPORARY AND PERMANENT MAGNETS



A motor has temporary and permanent magnets.



Some temporary magnets are electromagnets.

They have many uses. For example, large electromagnets are used to lift heavy pieces of iron. Electromagnets are also needed in telephones and bells.

# COMPLETING SENTENCES Complete the sentences with the choices below.

- |                                              |                                           |                                                                |
|----------------------------------------------|-------------------------------------------|----------------------------------------------------------------|
| permanent<br>temporary<br>magnetism<br>loses | Permalloy<br>steel<br>soft iron<br>alnico | alloy<br>lasting a short time<br>easily<br>lasting a long time |
|----------------------------------------------|-------------------------------------------|----------------------------------------------------------------|
- Temporary means \_\_\_\_\_.
  - Permanent means \_\_\_\_\_.
  - A magnet is permanent or temporary depending how long it keeps its \_\_\_\_\_.
  - Magnets that keep their magnetism for a short time are \_\_\_\_\_ magnets.
  - Magnets that keep their magnetism for a long time are \_\_\_\_\_.
  - Temporary magnets are made of \_\_\_\_\_.
  - Soft iron becomes a magnet \_\_\_\_\_. Soft iron also \_\_\_\_\_ its magnetism easily.
  - Most permanent magnets are made of \_\_\_\_\_.
  - Steel is an \_\_\_\_\_ of iron.
  - Extra strong permanent magnets are made of the alloys \_\_\_\_\_ and \_\_\_\_\_.

## MATCHING Match the two lists. Write the correct letter on the line next to each number.

- |                               |                                          |
|-------------------------------|------------------------------------------|
| 1. _____ permanent            | a) used for most permanent magnets       |
| 2. _____ temporary            | b) become extra strong permanent magnets |
| 3. _____ soft iron            | c) lasting a short time                  |
| 4. _____ steel                | d) lasting a long time                   |
| 5. _____ alnico and Permalloy | e) used to make temporary magnets        |

## TRUE OR FALSE Write T on the line next to the number if the sentence is true. Write F if the sentence is false.

- \_\_\_\_\_ All magnets have the same power.
- \_\_\_\_\_ All magnets keep their magnetism.
- \_\_\_\_\_ Soft iron becomes a magnet easily.
- \_\_\_\_\_ Soft iron loses its magnetism easily.
- \_\_\_\_\_ Steel becomes a magnet easily.
- \_\_\_\_\_ Steel loses its magnetism easily.
- \_\_\_\_\_ Soft iron magnets are permanent magnets.
- \_\_\_\_\_ Steel magnets are permanent magnets.
- \_\_\_\_\_ Alnico magnets are temporary magnets.
- \_\_\_\_\_ Every alloy has iron in it.

## THROW ONE OUT In each of the following sets of terms, one of the terms does not belong. Circle that term.

- temporary magnet    steel    soft iron
- steel    soft iron    permanent magnet
- iron    steel    alloy
- magnetic    paper    iron
- non-magnetic    paper    nickel

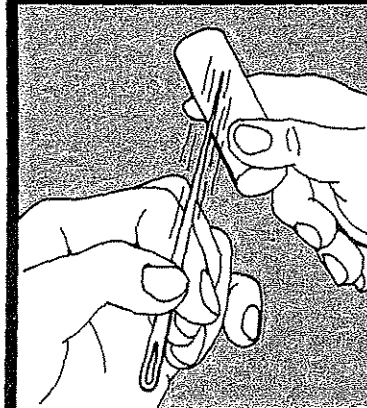
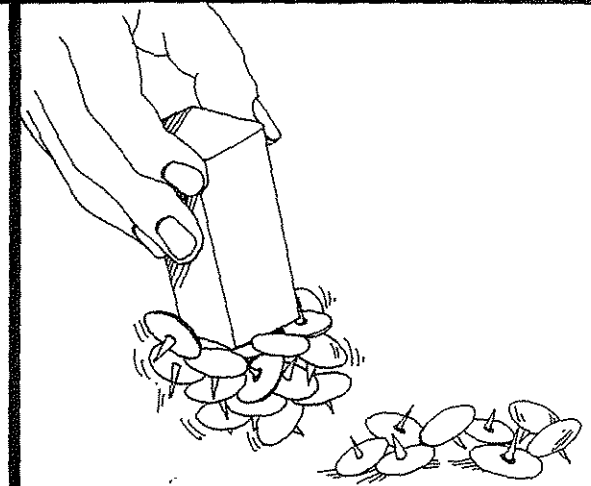
WORD Unscramble each of the following to form a word or term that  
SCRAMBLE you have read in this Aim.

1. MANTENREP
2. MERATYPOR
3. LEMPRYLOA
4. LESET
5. SROGNT

REACHING Does anything last forever? What about a giant mountain?  
OUT

## HOW CAN YOU MAKE A MAGNET?

14



contact: to touch

# AIM | How can you make a 14 | magnet?

There are several ways to make magnets. But you always have to start out with a magnetic substance. Two ways of making magnets are by contact and by stroking.

## MAGNETIZING BY CONTACT

The word contact means "touch." When a magnet touches a magnetic substance, the substance also becomes a magnet. The magnetic energy in the magnet makes the atoms in the substance line up. The atoms line up into domains. Contact magnetism can be passed on from one magnetic substance to another.

For example, look at Figure A on the facing page. The magnet has picked up tacks. Some tacks are not touching the magnet. They are only touching other tacks. The magnetism has been passed from one tack to the next one. Each tack has become a magnet by contact.

Magnets that are made by contact are very weak. The magnetism does not last long. Contact magnets are temporary magnets.

## MAGNETIZING BY STROKING

You can make a piece of steel into a magnet by stroking the steel with a permanent magnet. But you have to stroke the steel in a special way:

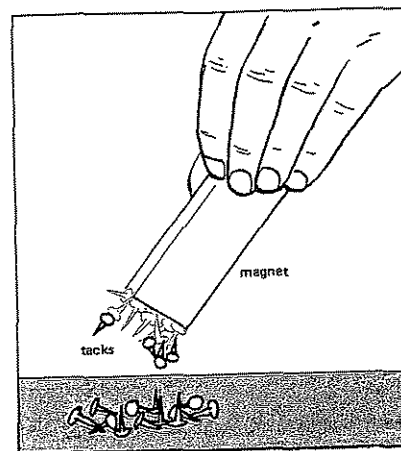
1. Stroke the steel with just one pole of the magnet.
2. Stroke the steel in just one direction.

Magnets that are made by stroking are permanent magnets. But they are usually weak magnets.

## WHAT DO THE PICTURES SHOW?

Look at each picture. Then answer the questions.

A.



Only the tacks in color are touching the magnet. . . . They have become magnets by contact.

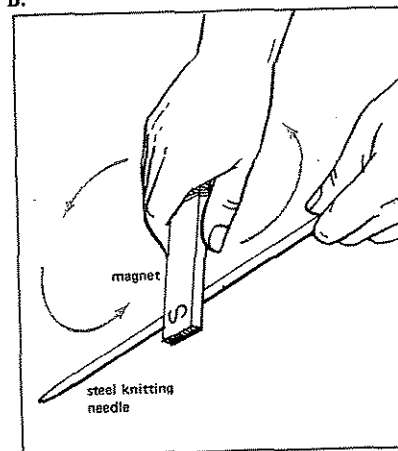
See how the magnetism is passed on from tack to tack.

Each tack becomes a magnet by contact.

1. Magnets made by contact are

\_\_\_\_\_ magnets.  
temporary, permanent

B.



2. The needle is becoming a magnet by \_\_\_\_\_  
contact, stroking

3. The stroking is done with \_\_\_\_\_  
only one pole, both poles of a permanent magnet.

4. The stroking is done \_\_\_\_\_  
back and forth, in only one direction

5. The needle is becoming a \_\_\_\_\_ magnet.  
permanent, temporary

6. The needle will be a \_\_\_\_\_ magnet.  
strong, weak

7. The needle is made of \_\_\_\_\_  
steel, soft iron

# COMPLETING SENTENCES Complete the sentences with the choices below. Two of these may be used twice.

permanent magnet      temporary one pole      touch in one direction only

- To "contact" means to \_\_\_\_\_.
- A magnetic substance becomes a magnet if it is touching a \_\_\_\_\_.
- Magnets made by contact are \_\_\_\_\_ magnets.
- Magnets made by stroking are \_\_\_\_\_ magnets.
- Steel can become only a \_\_\_\_\_ magnet.
- Soft iron can become only a \_\_\_\_\_ magnet.
- To make a magnet by stroking, you stroke steel \_\_\_\_\_, with only \_\_\_\_\_ of a permanent magnet.

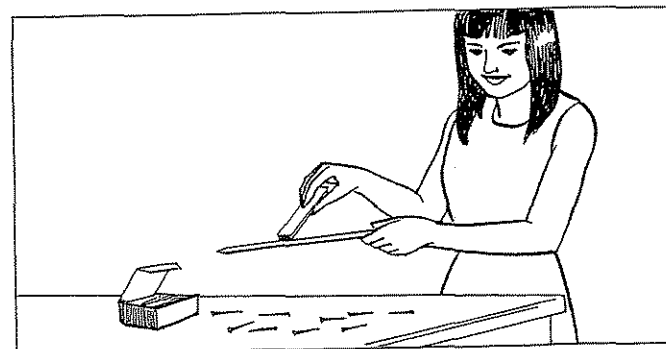
TRUE Write T on the line next to the number if the sentence is true.  
FALSE Write F if the sentence is false.

- \_\_\_\_\_ Every metal can become a magnet.
- \_\_\_\_\_ Soft iron can become a permanent magnet.
- \_\_\_\_\_ When you are standing, your feet are in contact with the ground.
- \_\_\_\_\_ Magnets made by contact are temporary magnets.
- \_\_\_\_\_ Steel can become a permanent magnet by stroking.
- \_\_\_\_\_ Back and forth stroking makes steel a magnet.
- \_\_\_\_\_ An alloy has one metal.
- \_\_\_\_\_ Alnico magnets are temporary magnets.
- \_\_\_\_\_ We need magnetism to make a magnet. (Think about this one.)

## TESTING A MAGNET

Make your own magnet by stroking.  
See how extra strokings change its strength.

What You Need permanent magnet  
steel knitting needle  
small steel straight pins



### How To Do the Experiment

- Place the tip of the needle into the pins. Then lift the needle. How many pins does it lift?

Write your answer on the chart.

- Stroke the needle twenty times in one direction with the magnet. How many pins does the needle lift?

Write the number on the chart.

- Do the same thing for 40, 60, 80, and 100 strokes. Write down the number of pins lifted.

| Number of Strokes | Number of Pins Lifted |
|-------------------|-----------------------|
| 0                 |                       |
| 20                |                       |
| 40                |                       |
| 60                |                       |
| 80                |                       |
| 100               |                       |



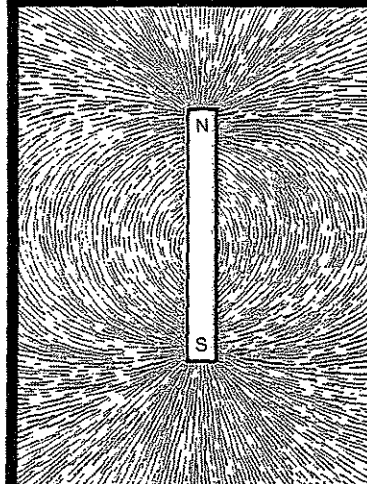
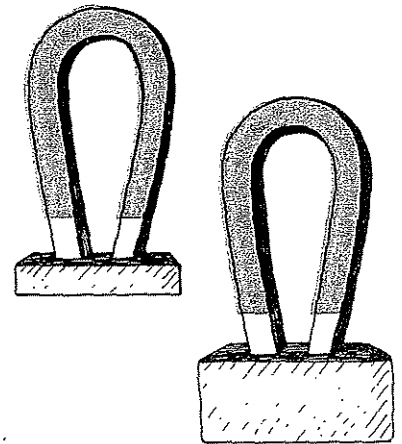
# What You Learned

4. The more you stroke the needle, the \_\_\_\_\_ pins it picks up.  
more, fewer
5. The more you stroke the needle, the \_\_\_\_\_ a magnet it becomes.  
stronger, weaker
6. There \_\_\_\_\_ a limit to how strong a magnet the needle can become.  
is, is not  
(Take a guess.)



## HOW CAN YOU MAKE A MAGNET BY INDUCTION?

15



**magnetic induction:** magnetic energy that is felt at a distance—without contact

# AIM | How can you make a 15 magnet by induction?

If you touch a fire, you get burned. But you don't have to actually touch a flame to get burned. You can get burned just by being near a flame—Heat energy spreads out. It can be felt at a distance from the flame.

Magnetic energy also spreads out. The energy can be felt at a distance from a magnet. Because of this, a magnetic substance can become a magnet just by being near a magnet.

This way of making a magnet is called induction [in DUCK shun]. Magnetic induction works best in a strong magnetic field. Induction works less well in a weak magnetic field. There can be no induction outside the magnetic field.

Both temporary and permanent magnets can be made by induction. Which kind you get depends on two things:

1. the kind of metal
2. the strength of the magnetic field.

Iron can become a temporary magnet only. Iron can be magnetized by induction very easily. Even a weak magnetic field will work. But iron does not keep its magnetism. It loses it when the magnetic field is removed.

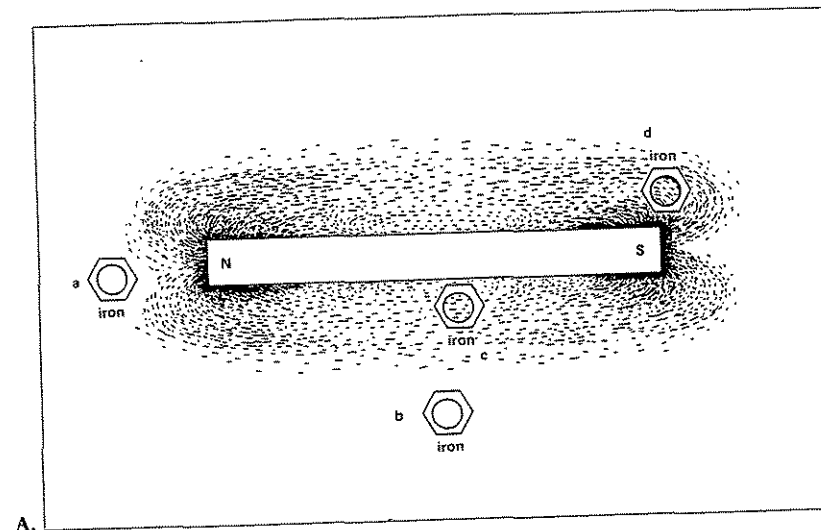
Steel can become a permanent magnet only. Steel cannot be magnetized easily by induction. A very strong magnetic field is needed. But steel keeps its magnetism once it does become a magnet.

The strong magnetic fields needed to make permanent magnets come from electricity.

## WHAT DOES THE PICTURE SHOW?

This diagram shows a magnet, its magnetic field, and four pieces of iron.

Study the diagram. Then answer the questions.



A.

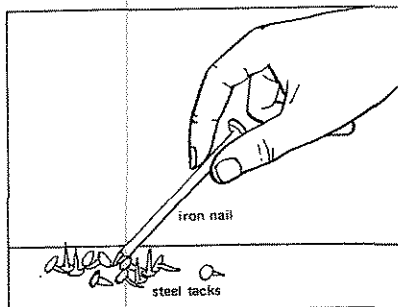
1. a) Which iron pieces are inside the magnetic field? \_\_\_\_\_  
b) Which iron pieces are outside the magnetic field? \_\_\_\_\_
2. a) Which iron pieces have become magnets? \_\_\_\_\_  
b) Which iron pieces have not become magnets? \_\_\_\_\_
3. Look at the pieces that have become magnets.  
a) Which one is stronger? \_\_\_\_\_  
b) Which one is weaker? \_\_\_\_\_
4. The iron pieces that have become magnets, have become magnets by \_\_\_\_\_  
contact, induction, stroking
5. Magnetic induction takes place \_\_\_\_\_ a magnetic field.  
inside, outside

## STUDYING MAGNETIC INDUCTION

What You Need magnet  
large iron nail  
small steel tacks

### How To Do the Experiment

A.



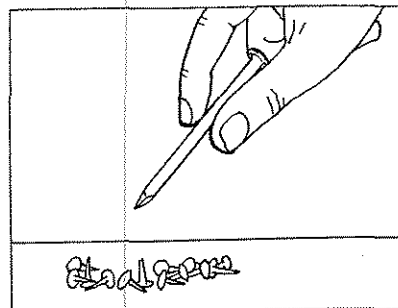
I. a) Hold the end of the nail in the pile of tacks (Figure A).

b) Lift the nail (Figure B).

1. The nail \_\_\_\_\_ lift  
does, does not  
any tacks.

2. This shows that the nail  
\_\_\_\_\_ a magnet.  
is, is not

B.



II. a) Place the nail in the tacks again.

b) With your other hand, hold the magnet close to the head of the nail. (Careful, don't let them touch.)

c) Lift the nail and magnet together (Figure C). (Careful, keep the distance between the nail and the magnet.)

3. The nail \_\_\_\_\_ lift  
does, does not  
any tacks.

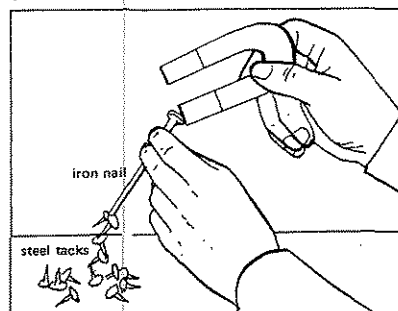
4. The nail \_\_\_\_\_ be-  
has, has not  
come a magnet.

5. The magnet and nail  
\_\_\_\_\_ touching.  
are, are not

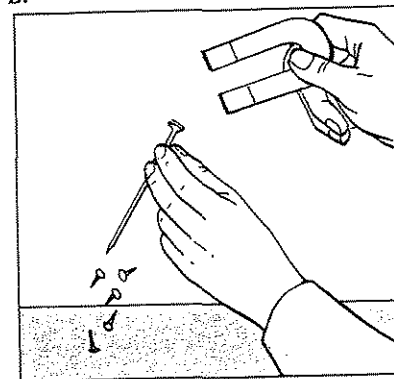
6. The nail \_\_\_\_\_ in  
is, is not  
the magnetic field of the magnet.

7. By what method has the nail be-  
come a magnet? \_\_\_\_\_

C.



D.



III. Pull the magnet away (Figure D).

8. The tacks \_\_\_\_\_  
do, do not  
drop.

9. The nail \_\_\_\_\_  
is still, is no longer  
in the magnetic field of the  
magnet.

10. The nail has \_\_\_\_\_  
kept, lost  
its magnetism.

11. Iron can become only a \_\_\_\_\_  
permanent, temporary  
magnet.

### COMPLETING SENTENCES

Complete the sentences with the choices below. Two of these may be used twice.

induction  
does not  
very strong  
very easily

contact  
weak  
permanent

temporary  
electricity  
stroking

- Two ways to make a magnet by touching are by \_\_\_\_\_ and by \_\_\_\_\_.
- Magnetism at a distance is called \_\_\_\_\_.
- Both \_\_\_\_\_ and \_\_\_\_\_ magnets are made by induction.
- Iron can become only a \_\_\_\_\_ magnet.
- Iron becomes a magnet \_\_\_\_\_.
- Even a \_\_\_\_\_ magnetic field can make iron a magnet by induction.
- Induction makes steel into a \_\_\_\_\_ magnet.
- Steel \_\_\_\_\_ become a magnet by induction easily.
- A \_\_\_\_\_ magnetic field is needed to make steel a permanent magnet by induction.
- Very strong magnetic fields come from \_\_\_\_\_.

TRUE OR FALSE Write T on the line next to the number if the sentence is true.  
Write F if the sentence is false.

1. \_\_\_\_\_ "Stroking" is magnetism at a distance.
2. \_\_\_\_\_ "Contact" magnetism is magnetism at a distance.
3. \_\_\_\_\_ "Induction" is magnetism at a distance.
4. \_\_\_\_\_ Induction works only inside a magnetic field.
5. \_\_\_\_\_ Iron can become a magnet by induction.
6. \_\_\_\_\_ Iron becomes a permanent magnet.
7. \_\_\_\_\_ Iron becomes a magnet easily.
8. \_\_\_\_\_ Steel can become a magnet by induction.
9. \_\_\_\_\_ Steel becomes a magnet easily by induction.
10. \_\_\_\_\_ Steel becomes a temporary magnet.

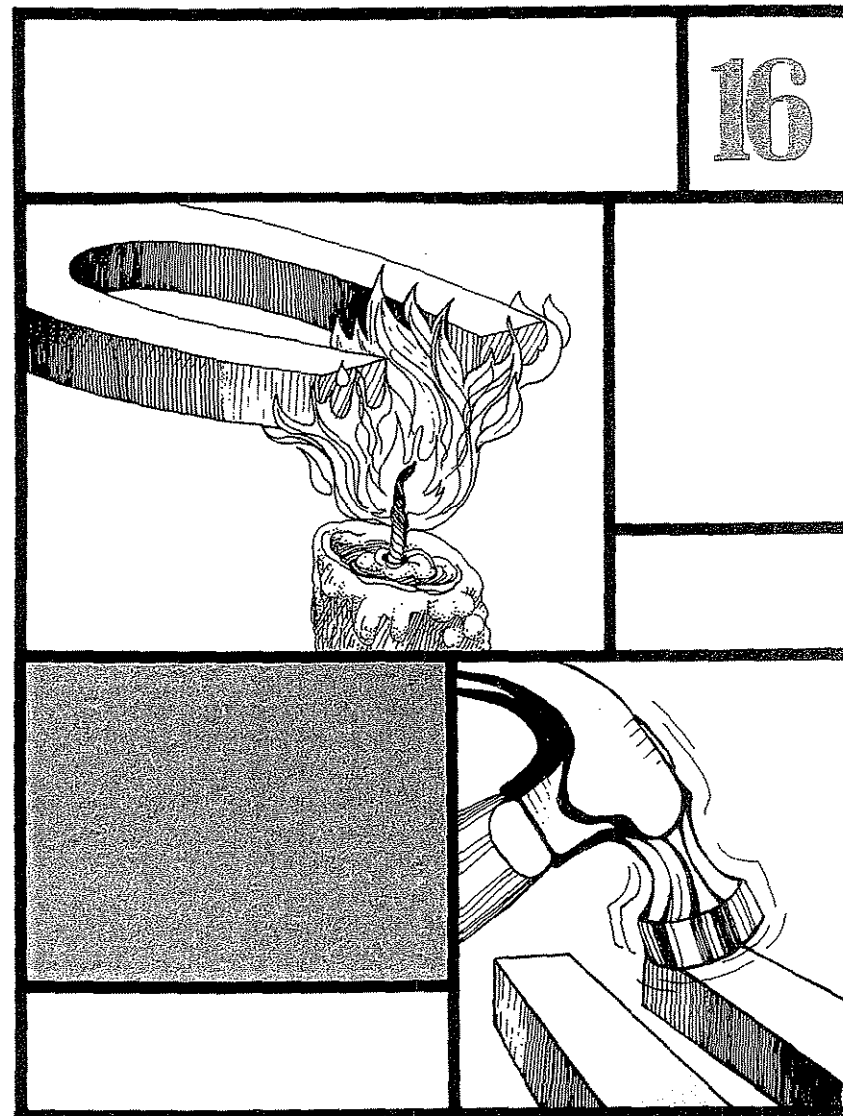
WORD SEARCH The words in this list are hidden in the groups of letters. Try to find each word. Draw a line around the word. The spelling may go in any direction: up-and-down, across, or diagonally.

MAGNET  
IRON  
ALLOY  
ALNICO  
NICKEL  
COBALT  
LODESTONE  
DOMAIN

|   |   |   |   |   |   |   |   |
|---|---|---|---|---|---|---|---|
| E | I | N | I | A | M | O | D |
| N | R | R | E | T | S | T | O |
| O | O | N | O | D | E | K | C |
| T | P | G | O | N | C | D | I |
| S | E | L | G | I | K | L | N |
| E | Y | A | Y | C | N | E | L |
| D | M | O | O | K | L | G | A |
| O | A | B | L | E | O | L | N |
| L | P | N | I | L | Y | I | A |
| O | D | C | O | B | A | L | T |

# HOW CAN YOU DESTROY A MAGNET?

16



# AIM | How can you destroy a magnet?

## 16 magnet?

Do you remember what happens when a magnetic substance becomes a magnet? The atoms group together. They become domains and line up. All the north poles face one way. All south poles face the other way. Its magnetic power is felt because the domains work together. They pull in only one direction.

What would happen if the domains faced in many directions? The magnet would grow weak. It would lose its magnetic power.

How do you make the domains go out of line? Here are three ways:

### HAMMERING

When you hammer a magnet, the domains go out of line. When you stop hammering, the domains do not line up again. The magnet is weakened or destroyed.

### HEATING RED HOT

When you heat a magnet until it is red hot, all the domains are upset. When the metal cools, the domains do not go back in line. The magnet loses all its power.

### STROKING BACK AND FORTH

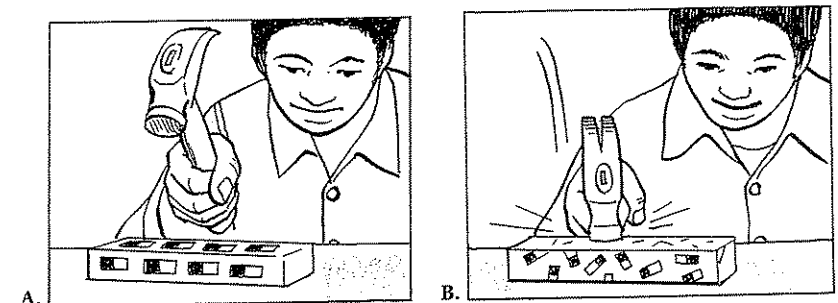
To make a magnet by stroking, you stroke the magnetic substance many times in one direction with a magnet.

But if you stroke the magnet back and forth with another magnet, the domains move out of line. They do not go back when the stroking stops.

A magnet can be made and destroyed over and over again.

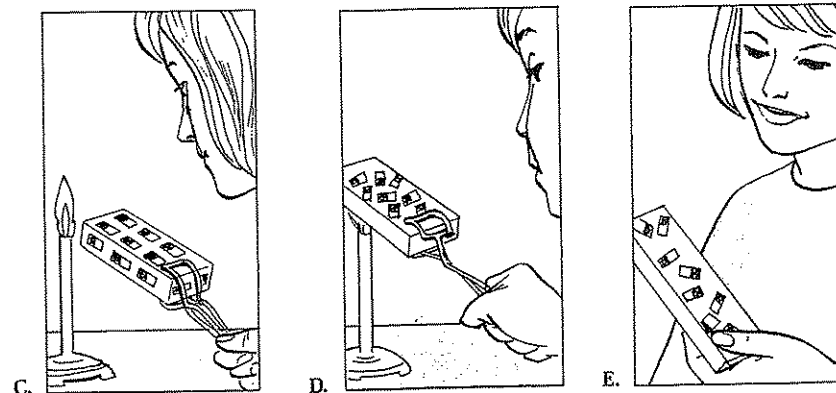
## WHAT DO THE PICTURES SHOW?

Look at each picture. Then answer the questions.



1. Hammering \_\_\_\_\_ domains.  
lines up, upsets

2. Hammering makes a magnet \_\_\_\_\_  
stronger, weaker



Atoms are always vibrating. This means that domains are always vibrating.

3. Heat makes domains vibrate \_\_\_\_\_  
slower, faster

4. Red-hot heat makes domains \_\_\_\_\_  
stay lined up, move out of line

5. Red-hot heat \_\_\_\_\_  
makes a magnet stronger, destroys a magnet

6. Cooling makes domains vibrate \_\_\_\_\_  
slower, faster

7. After cooling, the domains \_\_\_\_\_ go back in line.  
do, do not



**MATCHING** Match the two lists. Write the correct letter on the line next to each number.

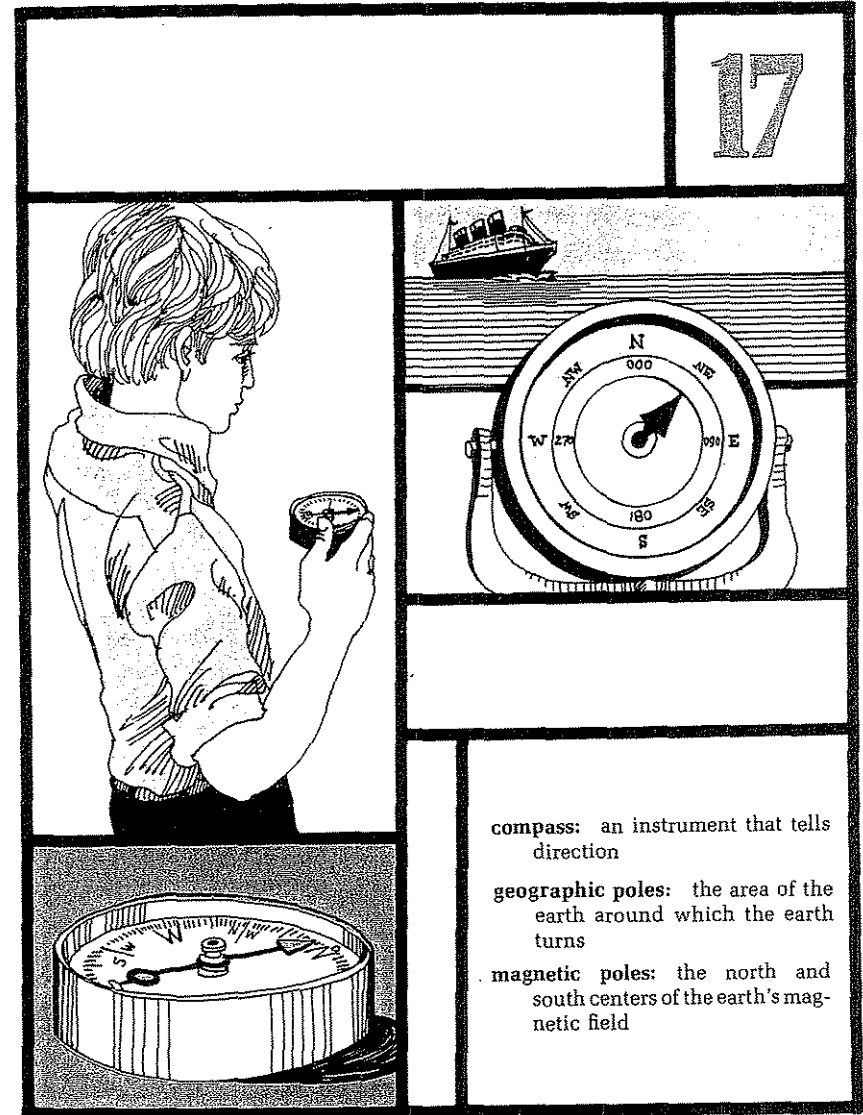
- |                                                                                  |                                |
|----------------------------------------------------------------------------------|--------------------------------|
| 1. _____ domain                                                                  | a) ways of destroying a magnet |
| 2. _____ heating red hot, hammering, stroking back and forth with another magnet | b) to shake rapidly            |
| 3. _____ magnetic field                                                          | c) group of lined-up atoms     |
| 4. _____ vibrate                                                                 | d) always vibrating            |
| 5. _____ atoms                                                                   | e) area of magnetic energy     |

**WORD SCRAMBLE** Unscramble each of the following words to form a word or term that you have read in this Aim.

1. RAMHEM \_\_\_\_\_
2. TENHAGI \_\_\_\_\_
3. GRITKONS \_\_\_\_\_
4. TAGMEN \_\_\_\_\_

# HOW DOES A COMPASS WORK?

17



**compass:** an instrument that tells direction

**geographic poles:** the area of the earth around which the earth turns

**magnetic poles:** the north and south centers of the earth's magnetic field

# AIM | How does a compass work?

17

Long ago, sailors made an important discovery. They held a string with a piece of magnetite tied to it. No matter which way the ship turned, the same end of the magnetite always pointed north. This was the first compass. It helped sailors find their way when they could not see land. It helped when the sun or the stars were hidden by clouds.

A compass still helps us find our way. Every ship and airplane has one. Maybe you have used one—on a hike or in a boat.

Our compasses are not made of magnetite on a string. A modern compass has a pointer or needle. The pointer is a thin permanent magnet. It rests on a sharp point so it can turn easily.

How does a compass work?

A compass needle acts like any magnet. It is attracted to an unlike pole of another magnet and repelled by a like pole.

How does a compass find direction?

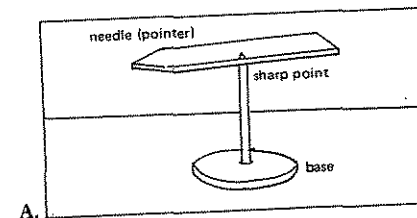
The earth is like a very large but weak magnet. It has a north pole, a south pole, and a magnetic field.

The earth's magnetic field pulls on the compass needle—it makes it turn. One end of the needle points north; the other end points south.

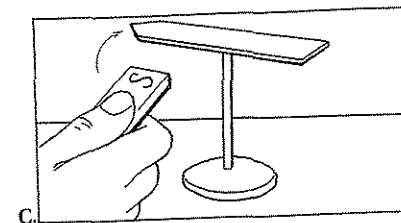
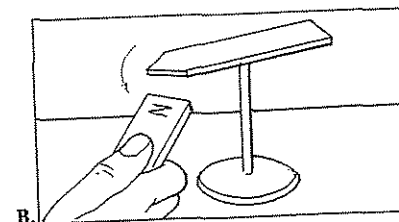
Don't get mixed up! The north magnetic pole and the south magnetic pole are not in exactly the same places as the geographic North Pole and South Pole.

## WHAT DO THE PICTURES SHOW?

Look at each picture. Then answer the questions.



A COMPASS

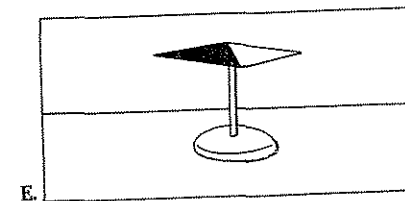
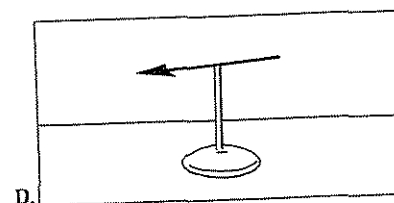


A compass needle acts like any magnet—it is attracted to an unlike pole of another magnet

and repelled by a like pole.

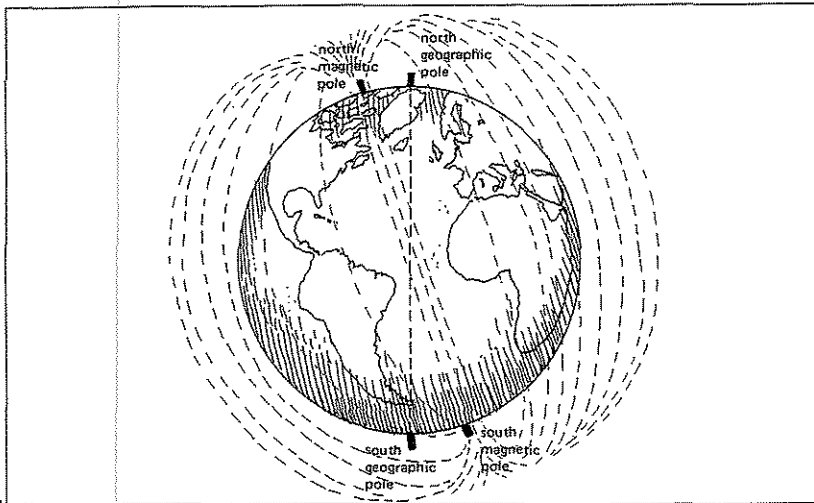
1. Which pole of the needle is closest to the magnet in Figure B? \_\_\_\_\_
2. Which pole of the needle is closest to the magnet in Figure C? \_\_\_\_\_
3. Which has a stronger magnetic field, the earth or the magnet? \_\_\_\_\_

A compass pointer is shaped like an arrow or a diamond.



4. Pointer D is shaped like \_\_\_\_\_  
an arrow, a diamond
5. The tip points \_\_\_\_\_  
north, south
6. Pointer E is shaped like \_\_\_\_\_  
an arrow, a diamond





F.

The earth has two kinds of north and south poles; the magnetic poles and the geographic poles.

They are not in the same places.

The earth spins around its geographic poles.

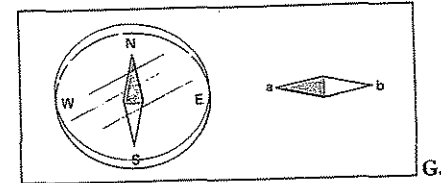
A compass needle points to the magnetic poles.

**TRUE OR FALSE** Write T on the line next to the number if the sentence is true.  
Write F if the sentence is false.

1. \_\_\_\_\_ A magnet makes a compass needle turn.
2. \_\_\_\_\_ A magnetic field makes a compass needle turn.
3. \_\_\_\_\_ The earth has a magnetic field.
4. \_\_\_\_\_ A compass needle always points north and south, even near a magnet.
5. \_\_\_\_\_ A compass needle is a permanent magnet.
6. \_\_\_\_\_ A compass needle is made of soft iron.
7. \_\_\_\_\_ The geographic poles are the same as the magnetic poles.
8. \_\_\_\_\_ A compass needle points to geographic north.

## FILL-IN QUESTIONS

Fill in the correct answer for each of the following.



G.

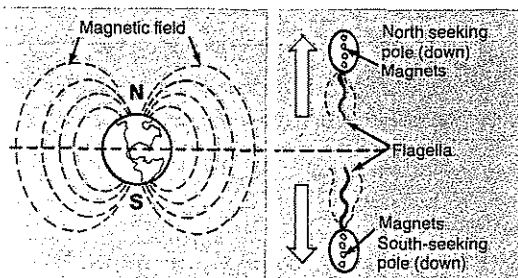
1. Which end points north? \_\_\_\_\_  
a, b
2. Which end points south? \_\_\_\_\_  
a, b
3. A compass tells direction because the earth acts like a very large \_\_\_\_\_.
4. Is the earth's magnetic field strong or weak? \_\_\_\_\_
5. A compass is placed near a magnet. The needle will turn to \_\_\_\_\_  
the earth's magnetic pole, the magnet
6. A magnetic needle pivots on a sharp point. What do you think the word "pivot" means? \_\_\_\_\_
7. Before the compass was discovered, sailors found their way by using \_\_\_\_\_  
the stars, arrows
8. In outer space, a compass \_\_\_\_\_ be used to tell direction.  
can, cannot

**MATCHING** Match the two lists. Write the correct letter on the line next to each number.

- |                                               |                                              |
|-----------------------------------------------|----------------------------------------------|
| 1. _____ earth                                | a) points north and south                    |
| 2. _____ compass needle                       | b) not in the same place                     |
| 3. _____ small piece of magnetite on a string | c) the points around which the earth rotates |
| 4. _____ geographic poles                     | d) huge but weak magnet                      |
| 5. _____ magnetic and geographic poles        | e) early compass                             |

# KEEPING UP WITH SCIENCE

## LIVING COMPASSES



Suppose you were blindfolded. You could not see a compass, the sun, the stars, or any familiar thing. Would you "know" where north or south is? You wouldn't! You couldn't! Without outside help, humans have no way of knowing direction. People have no built-in compasses.

Some bacteria, however, do have just that — built-in compasses. These compasses let the bacteria align themselves with the earth's magnetic field.

Why would bacteria want to know where north or south is? Bacteria, like all living things, need food. Bacteria without compasses cannot tell up and down. They just float around.

But bacteria are better off if they can swim down. "Down" is where food is—in the bottom sediment. Self-moving bacteria have tiny tails called *flagella*. The bacteria move by whipping the flagella.

There is a relationship between north and south and up and down. In the Northern Hemisphere down is north. In the Southern Hemisphere down is south.

Recently it has been discovered that the flagella of magnetic bacteria found in the Northern Hemisphere are opposite the north seeking pole of their built-in compasses. Therefore, the flagella moves the bacteria towards the north — which is

down.

The flagella of magnetic bacteria found in the Southern Hemisphere are opposite to the south seeking pole of their built-in compasses. Therefore, the flagella propel the bacteria towards the south—which is also down.

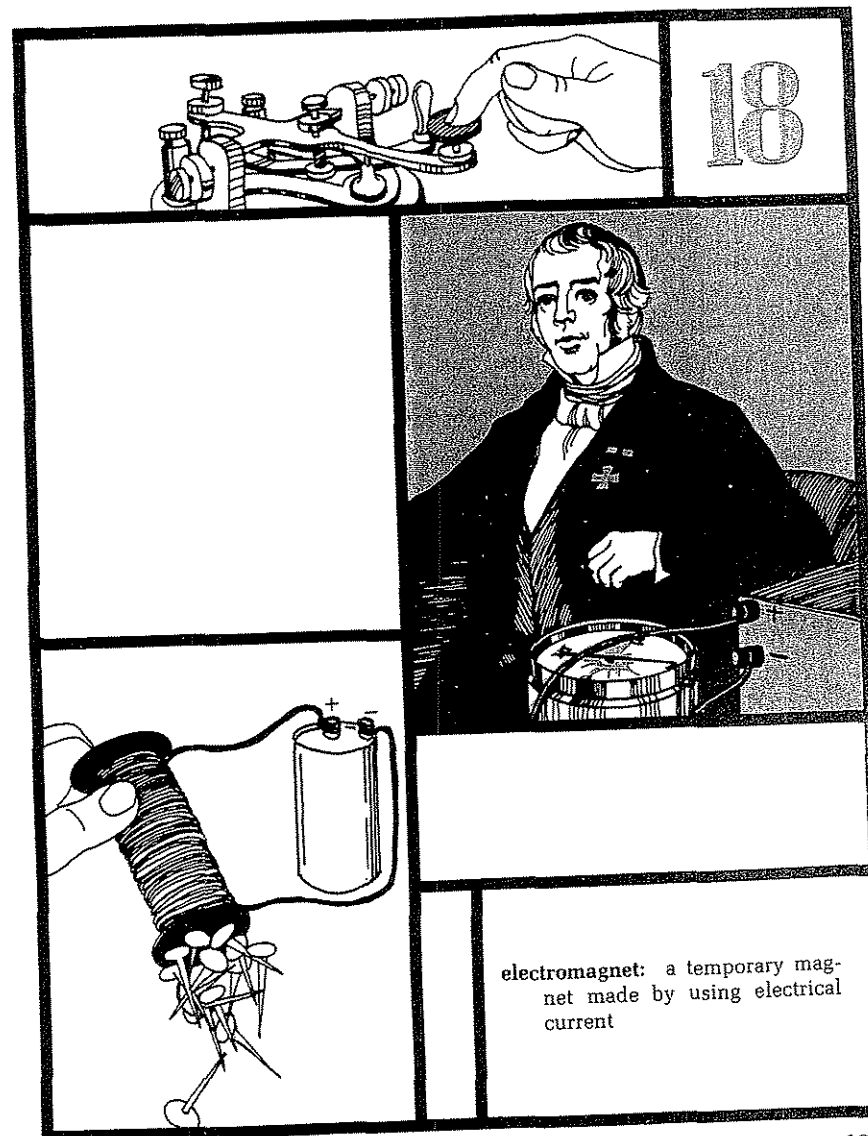
Near the equator, however, the earth's magnetic field is not up nor down. It is horizontal. Therefore, bacteria cannot find "down" by lining up with the earth's magnetic field. What do you suppose? So far, no magnetic bacteria have been found near the equator.

Bacteria "grow" their internal magnets from iron they take in from water.

Bacteria are not the only organisms that produce internal magnets. Magnetic iron has been found in the skulls of pigeons and in the stomachs of bees. Do these internal magnets help pigeons find their way home? Do they influence where bees build their hives? Do they help them find their way back to the hive? Scientists do not yet know. But these questions are being studied.

The discovery of magnetic bacteria has opened an interesting new field of scientific study. Do higher organisms contain magnetic iron? If so, how do these built-in compasses influence their behavior?

# WHAT IS AN ELECTROMAGNET?



electromagnet: a temporary magnet made by using electrical current

# AIM | What is an electromagnet?

18

Many important discoveries are made by accident. One of these discoveries was made by a Danish schoolteacher.

In 1819, Hans Oersted [UR sted] put a compass near an electric circuit. The compass needle turned toward the wire. Oersted turned off the electric current. The compass needle turned back to where it had been.

Oersted tried it again and again. The same thing happened each time. He knew that only a magnetic field can turn a compass needle. The magnetic field that turned the needle could have come only from the electricity!

Oersted had shown that an electric current gives off a magnetic field. This discovery led to many useful inventions. One of these inventions is the *electromagnet*. An electromagnet is a temporary magnet. It gets its magnetism from electricity. When the electricity stops, the magnetism stops. An electromagnet has many important uses.

Three things are needed to make an electromagnet:

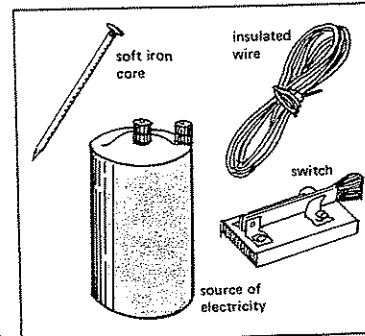
1. a soft iron core
2. a coil of insulated wire
3. a source of electricity.

A switch is helpful, but not necessary.

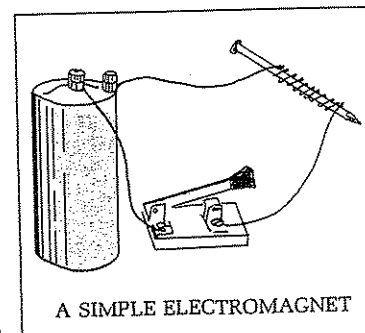
When you connect the parts, electricity moves through the wire. The electricity creates a magnetic field. The field magnetizes the core by induction. When the electricity stops, the core loses its magnetism.

## WHAT DO THE PICTURES SHOW?

Look at each picture. Then answer the questions.



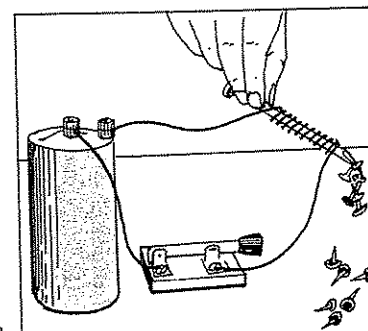
A.



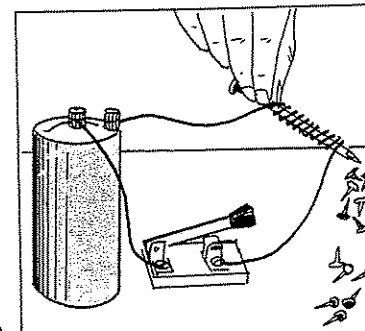
B.

I.

1. Which of the parts in Figure A must an electromagnet have? \_\_\_\_\_
2. Which part is helpful, but not necessary? \_\_\_\_\_



C.

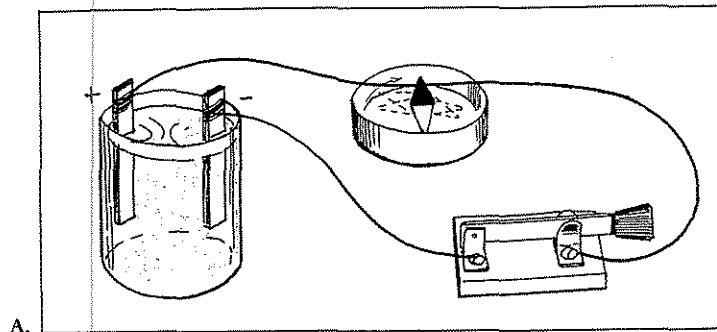


D.

II.

3. This circuit is \_\_\_\_\_ complete, incomplete
4. Electricity \_\_\_\_\_ is, is not \_\_\_\_\_ moving through the wire.
5. The iron core \_\_\_\_\_ has, has not \_\_\_\_\_ become a magnet.
6. If you open the switch, the tacks \_\_\_\_\_ drop, do not drop
7. An electromagnet is a \_\_\_\_\_ magnet.  
temporary, permanent

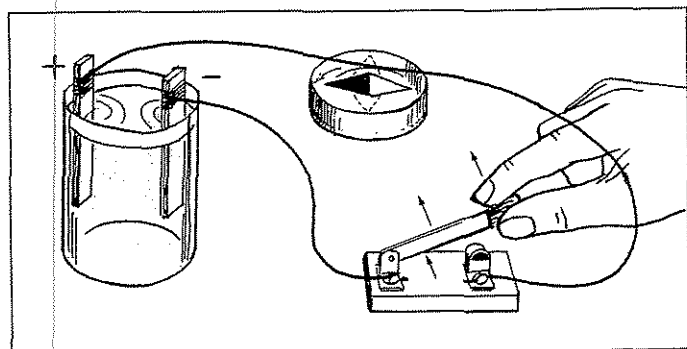
## OERSTED'S EXPERIMENT



A.

I. Oersted placed a compass near an electric circuit. The needle turned.

1. The compass needle turned \_\_\_\_\_ the wire.  
towards, away from



B.

II. Oersted turned off the current. The needle turned back to where it had been.

Oersted tried this over and over again. The same thing happened each time.

When the current was on, the compass needle pointed towards the wire. When the current was shut off, the needle turned back again.

2. What made the compass needle turn? \_\_\_\_\_  
Where did the magnetic field come from? \_\_\_\_\_
3. What did Oersted prove? \_\_\_\_\_

## COMPLETING SENTENCES Complete the sentences with the words below.

magnet  
soft iron core  
induction

temporary  
compass  
magnetic field

coil of insulated wire  
electromagnet  
source of electricity

1. Hans Oersted found out that electricity gives off a \_\_\_\_\_.
2. Magnetic energy makes iron become a \_\_\_\_\_.
3. Iron can become only a \_\_\_\_\_ magnet.
4. An \_\_\_\_\_ is a temporary magnet.
5. An electromagnet becomes a magnet by \_\_\_\_\_.
6. To make an electromagnet, you need: a \_\_\_\_\_, a \_\_\_\_\_, and a \_\_\_\_\_.
7. A \_\_\_\_\_ can tell us if electricity is moving through a wire.

TRUE OR FALSE Write T on the line next to the number if the sentence is true.  
FALSE Write F if the sentence is false.

1. \_\_\_\_\_ Permanent means lasting a very long time.
2. \_\_\_\_\_ An electromagnet is a permanent magnet.
3. \_\_\_\_\_ Soft iron loses its magnetism easily.
4. \_\_\_\_\_ Steel loses its magnetism easily.
5. \_\_\_\_\_ The core of an electromagnet is soft iron.
6. \_\_\_\_\_ When an electromagnet is connected, the core has a north and south pole.
7. \_\_\_\_\_ A magnetic field surrounds every wire.
8. \_\_\_\_\_ A compass turns when it is near any electrical wire.
9. \_\_\_\_\_ A temporary magnet can be switched on and off.
10. \_\_\_\_\_ A permanent magnet can be switched on and off.

} Careful these are tricky!

**MATCHING** Match the two lists. Write the correct letter on the line next to each number.

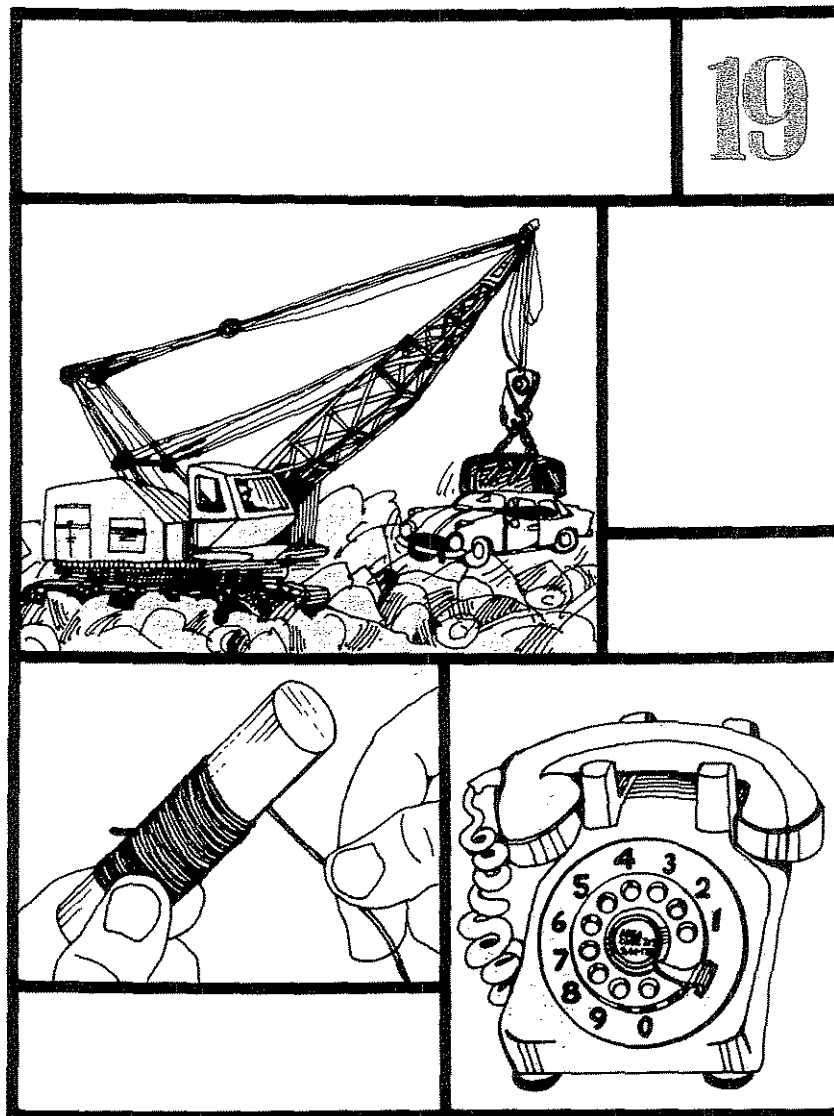
- |          |                                                               |                                                    |
|----------|---------------------------------------------------------------|----------------------------------------------------|
| 1. _____ | soft iron core, coil of insulated wire, source of electricity | a) turns towards magnetic field                    |
| 2. _____ | magnetic field                                                | b) parts of an electromagnet                       |
| 3. _____ | steel                                                         | c) discovered that electricity gives off magnetism |
| 4. _____ | compass                                                       | d) not good as electromagnet core                  |
| 5. _____ | Oersted                                                       | e) given off by electricity                        |

**THROW ONE OUT!** In each of the following sets of terms, one of the terms does not belong. Circle that term.

- |                  |                   |                        |
|------------------|-------------------|------------------------|
| 1. switch open   | magnetic field    | electricity moving     |
| 2. switch closed | no magnetic field | no electricity flowing |
| 3. electromagnet | soft iron core    | steel core             |
| 4. electromagnet | permanent magnet  | temporary magnet       |
| 5. compass       | magnetic pole     | geographic pole        |

# WHAT MAKES AN ELECTROMAGNET STRONGER?

19



# AIM | What makes an 19 | electromagnet stronger?

You may have seen an electromagnet in a junk yard. It is huge. It lifts whole cars. Inside your telephone is a tiny electromagnet. It lets you hear people speak. The huge electromagnet in the junk yard is strong. The tiny electromagnet in your telephone is weak. Electromagnets of different strengths are needed for different jobs.

Weak electromagnets do small jobs. Strong electromagnets do big jobs. The stronger an electromagnet is, the more work it can do.

When an electromagnet is made, the designer thinks about the job it must do. Then the correct size is made for the job.

How can you make an electromagnet stronger? There are three ways:

1. Wind more wire around the coil.
2. Use a stronger electric current.
3. Use a larger core.

There is a limit to how strong an electromagnet can be made. The core can be "filled" with magnetism. Then it cannot be made stronger.

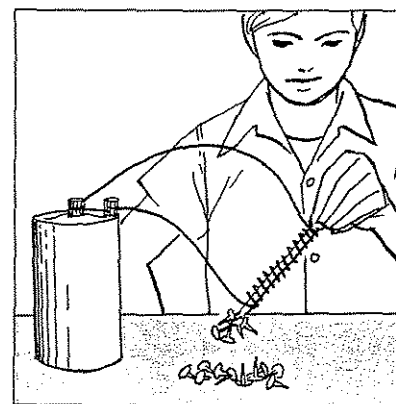
Try the experiment on the next page. You will see for yourself how an electromagnet can be made stronger.

## EXPERIMENTING WITH ELECTROMAGNETS

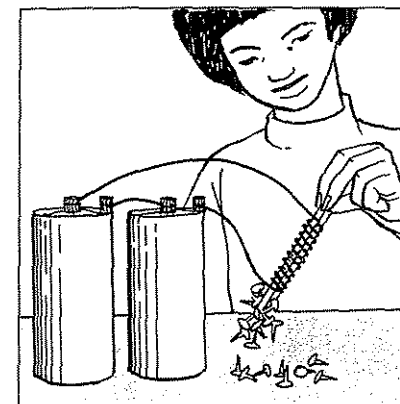
**What You Need** two 1½-volt dry cells  
two large iron nails  
insulated wire  
switch  
small steel tacks

### How To Do the Experiment

1. Hook up your electromagnet. The chart below shows six different ways.
2. Test each hook up.



A. One dry cell



B. Two dry cells

Count how many tacks the electromagnet lifts. Write the numbers on the chart.

|    | Number of<br>Wire Turns | Number of<br>Dry Cells | Number of<br>Cores (Nails) | Number of Tacks<br>Picked Up |
|----|-------------------------|------------------------|----------------------------|------------------------------|
| 1. | 20                      | 1                      | 1                          |                              |
| 2. | 40                      | 1                      | 1                          |                              |
| 3. | 20                      | 2                      | 1                          |                              |
| 4. | 20                      | 1                      | 2                          |                              |
| 5. | 40                      | 2                      | 1                          |                              |
| 6. | 40                      | 2                      | 2                          |                              |

### What You Learned

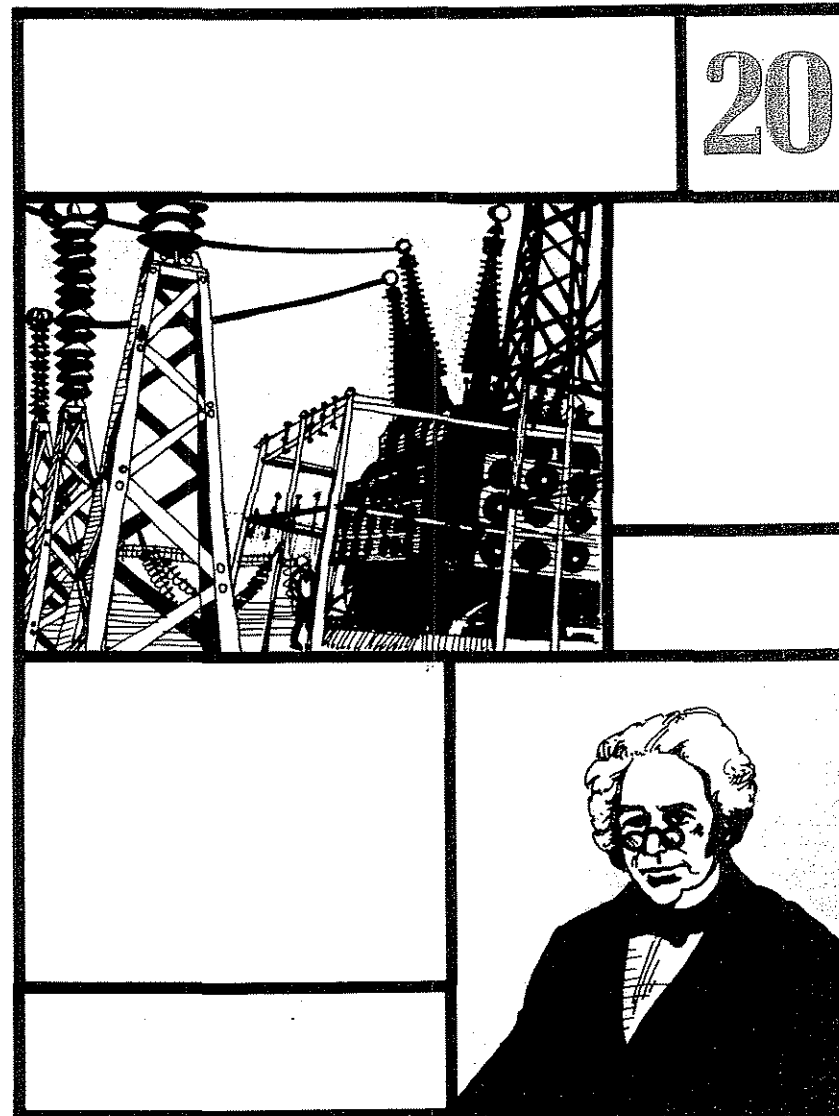
1. More wire turns make an electromagnet \_\_\_\_\_.  
stronger, weaker
2. Stronger voltage makes an electromagnet \_\_\_\_\_.  
stronger, weaker
3. A larger core makes an electromagnet \_\_\_\_\_.  
stronger, weaker
4. Fewer wire turns make an electromagnet \_\_\_\_\_.  
stronger, weaker
5. Weaker voltage makes an electromagnet \_\_\_\_\_.  
stronger, weaker
6. A smaller core makes an electromagnet \_\_\_\_\_.  
stronger, weaker

### ANSWER THESE QUESTIONS

1. An electromagnet is a \_\_\_\_\_ magnet.  
temporary, permanent
2. Name the three important parts of an electromagnet.  
\_\_\_\_\_  
\_\_\_\_\_
3. What kind of metal is used as the core of an electromagnet? \_\_\_\_\_
4. List three ways to make an electromagnet stronger.  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

## HOW CAN YOU USE A MAGNET TO MAKE ELECTRICITY?

20



# AIM | How can you use a magnet 20 | to make electricity?

Magnetism and electricity are not the same. But they are related. You have learned that electricity gives off magnetic energy. The opposite is also true—magnetism gives off electric energy.

Michael Faraday [FA ruh day] was a British scientist. In 1831, he learned that magnetic energy can be used to make electricity. Faraday tried two experiments:

1. He moved a permanent magnet back and forth inside a coil of insulated wire. This produced an electric current.
2. Then he moved the coil back and forth around the magnet. Again, he produced an electric current.

Faraday had made the first electric generator. It was a simple generator. It produced weak electricity. But it was a generator.

How does a generator make electricity? Magnetic lines of force surround every magnet. Movement through the lines of force is called *breaking* or *cutting* the lines of force. If a coil of insulated wire breaks the lines of force, electrons in the wire move. That means electricity is produced. We can measure weak electrical current with a galvanometer.

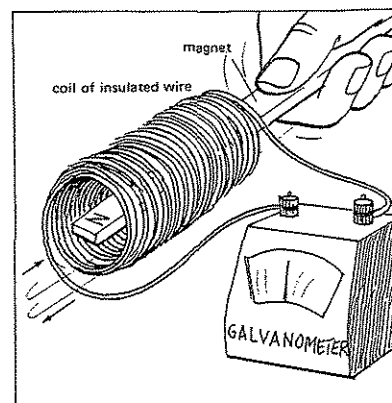
There are two ways of breaking the lines of force: 1) move the coil or 2) move the magnet.

In most generators, the coil moves. It turns between the poles of a permanent magnet. If the coil turns faster—or if a stronger magnet is used—you get a stronger electrical current.

Giant generators are needed to make all our electricity.

WHAT DOES THE PICTURE SHOW? Look at the picture. Then answer the questions.

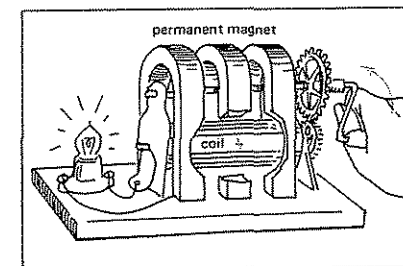
A.



1. The instrument that is making electricity is called a \_\_\_\_\_ generator, galvanometer
2. a) The instrument that is measuring the electricity is called a \_\_\_\_\_ generator, galvanometer  
b) This instrument measures \_\_\_\_\_ electricity.  
strong, weak
3. In this simple generator, the \_\_\_\_\_ magnet, coil is moving.

4. If the coil would move instead, the electricity would \_\_\_\_\_ stop, be the same
5. If you move the coil or magnet slower, you get \_\_\_\_\_ stronger, weaker electricity.
6. If you move the coil or magnet faster, you get \_\_\_\_\_ stronger, weaker electricity.
7. If you use a stronger magnet, you get \_\_\_\_\_ stronger, weaker electricity.
8. If you use a weaker magnet, you get \_\_\_\_\_ stronger, weaker electricity.

B.



Inside A Generator

The turning coil "breaks" the lines of force of the magnet.

This makes electricity move through the wire.



**COMPLETING SENTENCES** Complete the sentences with the choices below. One of these words may be used twice.

|                                                                       |                                                             |                                               |
|-----------------------------------------------------------------------|-------------------------------------------------------------|-----------------------------------------------|
| move<br>electricity<br>turn the coil faster<br>coil of insulated wire | Faraday<br>magnetic energy<br>weak<br>use a stronger magnet | permanent magnet<br>galvanometer<br>generator |
|-----------------------------------------------------------------------|-------------------------------------------------------------|-----------------------------------------------|

1. Electricity gives off \_\_\_\_\_.
2. Magnetic energy can be used to make \_\_\_\_\_.
3. The English scientist named \_\_\_\_\_ found out that magnetism can be used to make electricity.
4. The machine that makes electricity is called a \_\_\_\_\_.
5. The necessary parts of an electric generator are a \_\_\_\_\_ and a \_\_\_\_\_.
6. To make electricity, either the wire or the magnet must \_\_\_\_\_.
7. In most generators, the \_\_\_\_\_ moves.
8. A \_\_\_\_\_ measures weak electricity.
9. Weak magnets can make only \_\_\_\_\_ electricity.
10. Two ways to make stronger electricity are \_\_\_\_\_ and \_\_\_\_\_.

**MATCHING** Match the two lists. Write the correct letter on the line next to each number.

- |                                            |                                                      |
|--------------------------------------------|------------------------------------------------------|
| 1. _____ Michael Faraday                   | a) made first generator                              |
| 2. _____ magnet and coil of insulated wire | b) discovered that electricity gives magnetic energy |
| 3. _____ galvanometer                      | c) measures weak voltage                             |
| 4. _____ electricity                       | d) parts of a generator                              |
| 5. _____ Oersted                           | e) moving electrons                                  |

**TRUE OR FALSE** Write T on the line next to the number if the sentence is true. Write F if the sentence is false.

1. \_\_\_\_\_ A generator needs electricity to work.
2. \_\_\_\_\_ A generator makes electricity.
3. \_\_\_\_\_ We get electricity only from generators.
4. \_\_\_\_\_ Most of our electricity comes from generators.
5. \_\_\_\_\_ A generator must have a magnet.
6. \_\_\_\_\_ A generator must have a coil of insulated wire.
7. \_\_\_\_\_ A magnet and coil always give electricity.
8. \_\_\_\_\_ A magnet gives off electric energy.
9. \_\_\_\_\_ A magnet can make electrons move.
10. \_\_\_\_\_ Electricity is moving electrons.

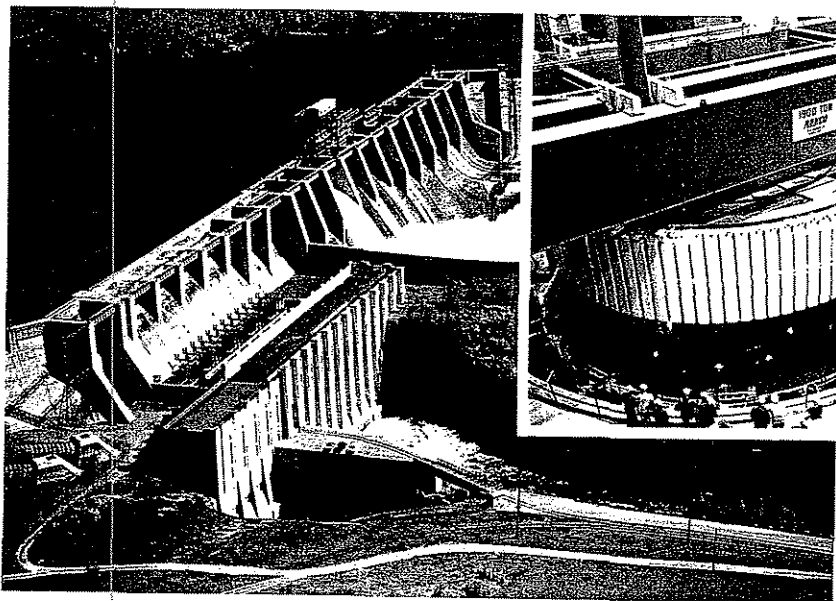
**FILL-IN QUESTIONS** Fill in the correct answer for each of the following. (Turn back to previous Aims if necessary).

1. List the three necessary parts of an electromagnet. \_\_\_\_\_
2. Name the part of an electromagnet that is useful but not necessary. \_\_\_\_\_
3. Who discovered that electricity gives off magnetism? \_\_\_\_\_
4. What kind of magnet is an electromagnet? \_\_\_\_\_
5. List the three ways to make an electromagnet stronger. \_\_\_\_\_
6. Can an electromagnet be made stronger and stronger without stopping? \_\_\_\_\_
7. List two uses of the electromagnet. \_\_\_\_\_
8. What did Michael Faraday discover? \_\_\_\_\_
9. Name the machine that makes electricity. \_\_\_\_\_
10. List the important parts of a generator. \_\_\_\_\_

WORD SCRAMBLE Unscramble each of the following to form a word or term that you have read in this Aim.

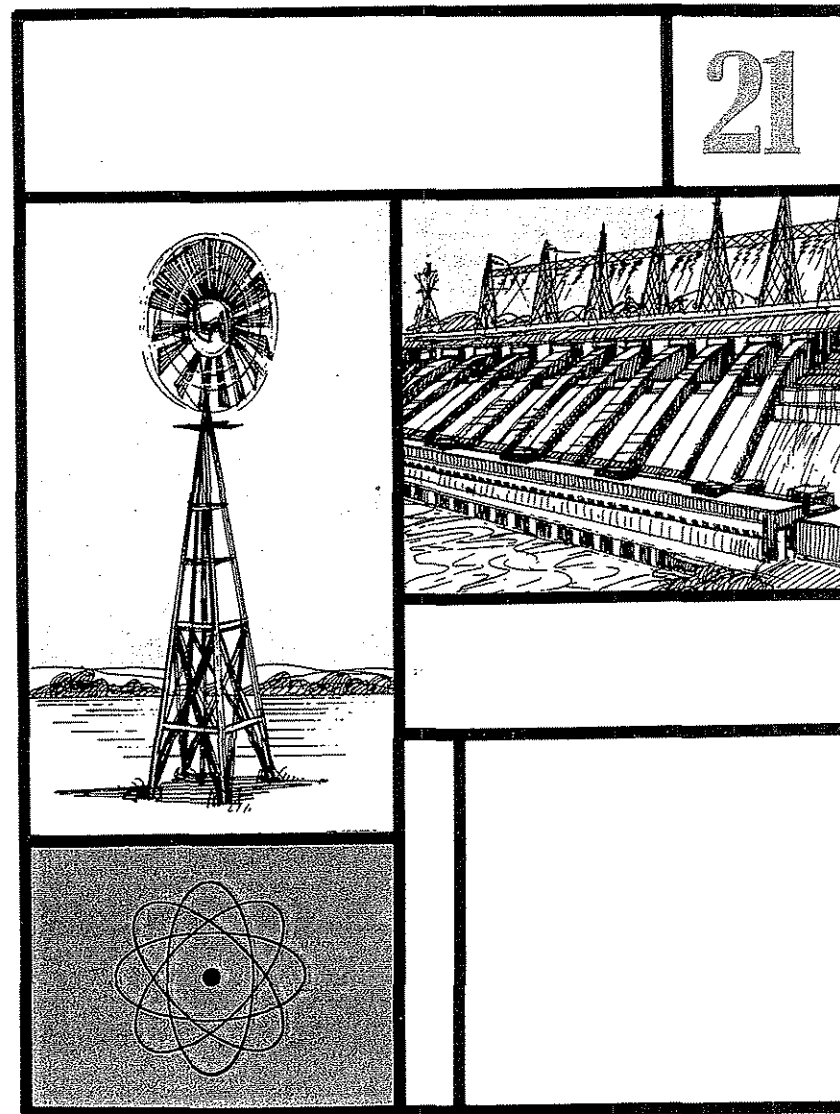
1. TENRAGREO
2. GATMEN
3. LOIC
4. LOVGATE
5. TRUNREC

REACHING OUT Water power turns the coils of some generators. What are some other ways to turn the coil?



## HOW DOES A GENERATOR COIL TURN?

21



# AIM | How does a generator coil 21 | turn?

Electricity is a form of energy. It can make things move.

A generator produces electricity. Its coil turns between the poles of a permanent magnet. But what turns the coil?

Any form of energy can turn a generator coil. Even wind can be used. But wind is not reliable. Wind does not blow all the time. And, in most places, it does not blow very hard. At best, wind produces only small amounts of electricity.

Swift-moving water is a reliable way to produce electricity. Places like Niagara Falls have huge generators. They produce electricity for hundreds of thousands of people.

Dams also produce large amounts of electricity. A dam stores water. When the water is let out, it turns generator coils.

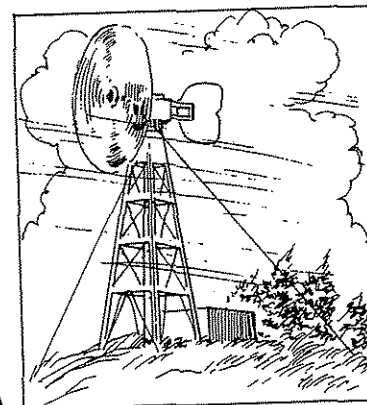
Places with powerful waterfalls or dams are important in producing electricity. But most places do not have falls or dams. Most electricity is produced by steam power. Fuels, like coal, oil, and gas, boil water. Boiling water produces steam. The force of the steam turns generator coils.

Some energy for making electricity comes from atomic fuel.

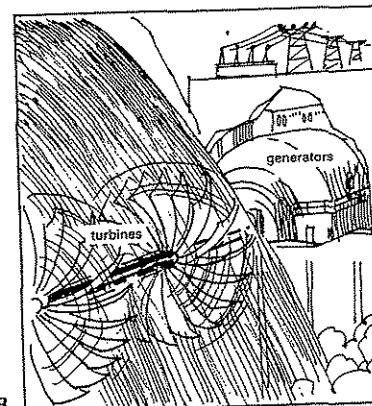
Atomic energy and fuel burning have a serious problem—they pollute. Coal, oil, and gas burning gives off unwanted gases. Burning coal also gives off solid wastes. Atomic energy gives off dangerous radiation. There is also a danger of an atomic explosion. Thousands of people can die.

Scientists are trying to find cheap and “clean” ways to produce electricity.

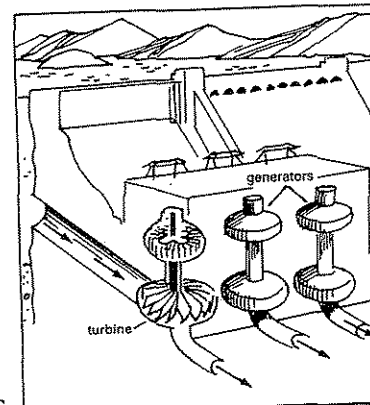
## ENERGY FOR GENERATORS



A.



B.



C.

In Figure A the energy of wind is spinning the blades, which turn the coils of a generator.

1. Does wind blow all the time in most places? \_\_\_\_\_
2. Does wind always blow hard? \_\_\_\_\_
3. Is wind energy a reliable way of producing electricity? \_\_\_\_\_

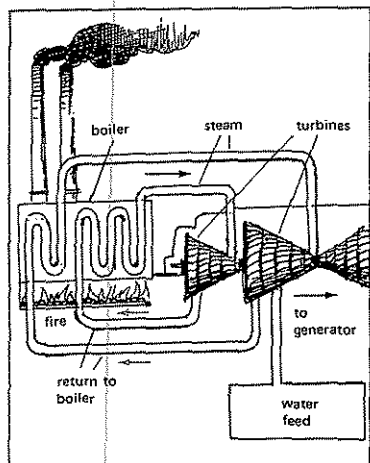
Figure B shows a waterfall. Swift-moving water is spinning the turbines, which turn the coils of the generators.

4. Will there always be moving water here? \_\_\_\_\_
5. Is swift-moving water a reliable way of producing electricity? \_\_\_\_\_

Figure C shows a dam with turbines and generators.

6. How is Figure C different from Figure B? \_\_\_\_\_
7. Do wind and moving water give off pollution? \_\_\_\_\_

D.



The energy of steam is spinning the turbines, which turn the coils of the generator.

8. a) Name three kinds of fuels we burn to make steam.

---



---



---

- b) What other kind of energy produces a great amount of heat.

---

9. Does burning fuel give off pollution?

---

10. a) What kind of pollution do coal, oil, and gas give off?

---

- b) What other kind of pollution does coal give off?

---

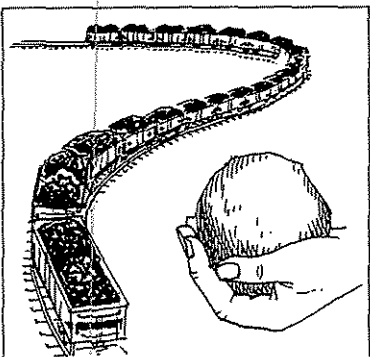
11. a) Does atomic energy pollute? \_\_\_\_\_

- b) What kind of pollution does atomic energy give off? \_\_\_\_\_

- c) Is this the only danger in using atomic energy? \_\_\_\_\_

- d) What other danger is there? \_\_\_\_\_

E.



### COMPARING COAL ENERGY WITH ATOMIC ENERGY

Just .45 kilograms (1 lb) of uranium (atomic fuel) gives the same energy as 1,043,262 kilograms (2,300,000 lbs) of coal.

This much coal would fill about 20 freight cars.

### COMPLETING SENTENCES

Complete the sentences with the choices below. Two of these may be used twice.

coil of insulated wire  
gas  
steam  
move  
pollution

cannot  
generator  
oil  
wind

coal  
swift-moving water  
permanent magnet  
atomic

- Electricity is made with a \_\_\_\_\_.
- The two important parts of a generator are a \_\_\_\_\_ and a \_\_\_\_\_.
- In a generator, either the coil or the magnet must \_\_\_\_\_.
- In most generators, the \_\_\_\_\_ turns.
- Three forces that can turn a generator coil are \_\_\_\_\_, \_\_\_\_\_, and \_\_\_\_\_.
- We \_\_\_\_\_ rely upon wind to produce electricity.
- Boiling water produces \_\_\_\_\_.
- Three fuels we burn to produce steam are \_\_\_\_\_, \_\_\_\_\_, and \_\_\_\_\_.
- The energy that gives the greatest heat is \_\_\_\_\_ energy.
- Atomic energy and burning fuels create \_\_\_\_\_.

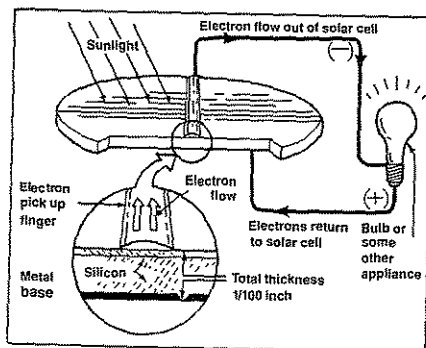
### MATCHING

Match the two lists. Write the correct letter on the line next to each number.

- |                         |                                      |
|-------------------------|--------------------------------------|
| 1. _____ generator      | a) unwanted things                   |
| 2. _____ pollution      | b) radiation danger                  |
| 3. _____ coal, oil, gas | c) holds water                       |
| 4. _____ atomic energy  | d) machine that produces electricity |
| 5. _____ dam            | e) fuels                             |

# KEEPING UP WITH SCIENCE

## PLUGGING INTO THE SUN



Scientists have discovered a way of turning sunlight directly into electricity. It is called photovoltaics.

Photovoltaics depends upon the solar cell. Today's solar cell is made of a slice of a single silicon crystal placed upon a very thin metal base. The base is laced with micro-thin wires. Each cell is about 3 to 6 inches in diameter (or smaller) and is thinner than a human hair.

When sunlight strikes the silicon atoms of a solar cell, their electrons are pushed into the wires. The moving electrons are an electric current. After the electrons do their job, such as lighting a bulb, they return to their silicon atoms in the solar cell. They are now ready to be pumped out again...and again. A solar cell can work without stopping for 30 years.

Solar cells have been used mainly for special jobs like powering satellites. Today, you can buy solar-powered watches, pocket calculators, and even portable radios. These require only weak electric currents.

Why don't we use photovoltaic elec-

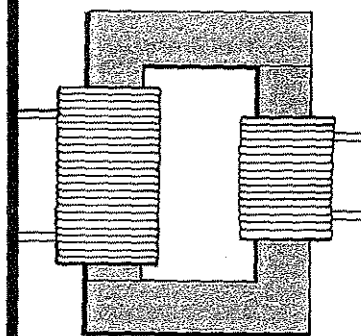
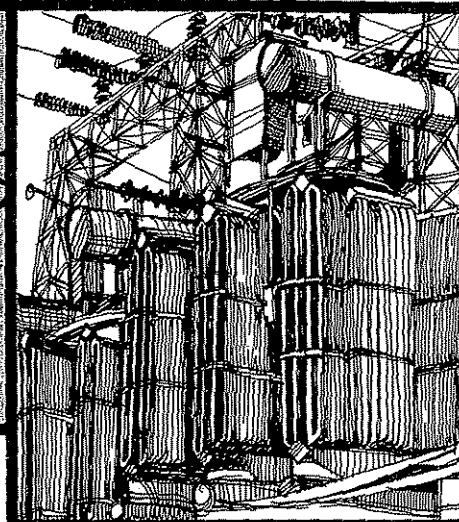
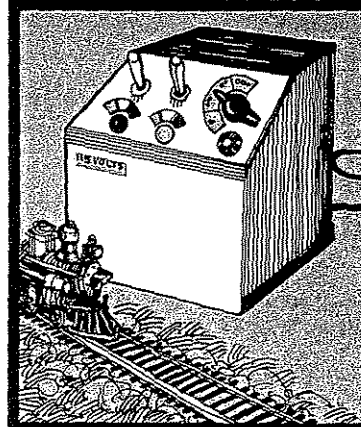
tricity for bigger everyday jobs—like lighting our homes or running factory motors? The answer, in one word, is MONEY. In its present form, photovoltaic electricity is too expensive. A single solar cell produces only a very weak current. Much stronger currents are needed to power a home or factory. To achieve this power, many solar cells must be bunched together. And they are still costly. At present you would need \$12,000 worth of solar cells to power an ordinary toaster.

Looks bad for photovoltaics? Not at all! Scientists are rapidly developing ways to bring down the cost greatly. By the year 2000, solar cells are expected to supply 20 percent of our nation's electricity.

However, solar cells need help. At night, no solar electricity is produced. On cloudy days, the electric output is reduced to almost nothing. Batteries can help at these times. But battery technology must be greatly improved. Batteries could store solar-cell electricity during peak sun hours. Regular generator-produced electricity can also be used.

# WHAT IS A TRANSFORMER?

22



transformer: a device that changes the voltage of alternating current

# AIM What is a transformer?

## 22

Some electric passenger trains need huge electromotive force to turn their wheels—as much as 11,000 volts. An electric toy train uses only about 18 volts. The wires in most homes carry about 115 volts. Some appliances need high voltage to work. Some need low voltage.

Sometimes voltage must be made stronger; sometimes it must be made weaker to suit different devices.

How can we change voltage? By using a transformer. There are large and small transformers. But they all work the same way.

A transformer has three main parts: (Figure A).

- a soft iron core, and
- two different coils of insulated wire wrapped around the core.

One of these coils is called the primary coil. The primary coil is connected to the electricity coming in.

The other coil is called the secondary coil. The secondary coil is connected to the appliance.

There are two kinds of transformers—step-up, and step-down.

### I. A step-up transformer increases voltage.

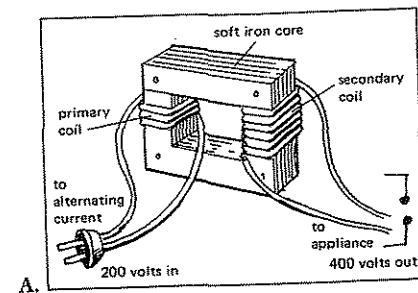
In a step-up transformer, the secondary coil is wrapped around the core more times than the primary coil.

### II. A step-down transformer decreases voltage.

In a step-down transformer, the primary coil is wrapped around the core more times than the secondary coil.

There are two kinds of electric current—direct current (DC) and alternating current (AC). Transformers work only with alternating current.

## A STEP-UP TRANSFORMER

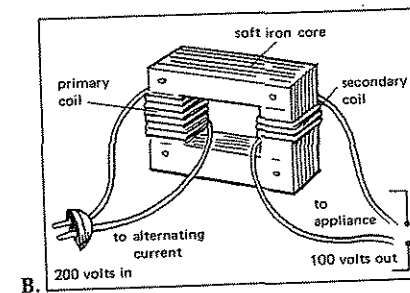


This step-up transformer has 3 turns in the primary coil.

The secondary coil has 6 turns. This is twice the turns as the primary coil. It doubles the voltage.

For example: If you start out with 200 volts, you end up with 400 volts.

## A STEP-DOWN TRANSFORMER



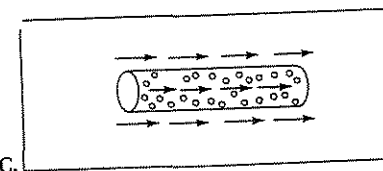
This step-down transformer has 6 turns in the primary coil.

The secondary coil has 3 turns. This is one half the turns as the primary coil. It makes the voltage half as strong.

For example: If you start out with 200 volts, you end up with 100 volts.

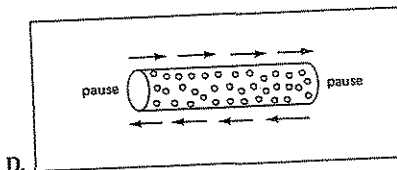
## DIFFERENCES BETWEEN DIRECT CURRENT AND ALTERNATING CURRENT

In DIRECT CURRENT:



- a) The electricity moves through the circuit in one direction only.
- b) It does not move back and forth.
- c) Direct current does not stop and go. REMEMBER THIS.

In ALTERNATING CURRENT:



- a) The electricity moves back and forth many times a second.
- b) Each time the electricity changes direction, it stops for a moment. It happens very fast.
- c) Remember—alternating current stops and goes, stops and goes, stops and goes.

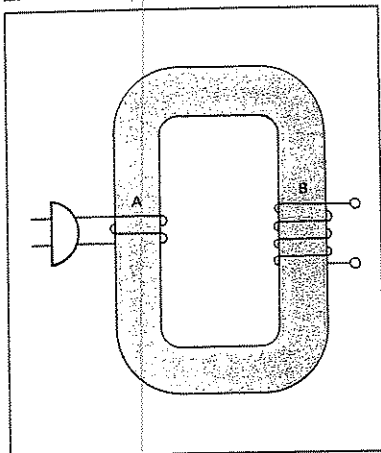
## A TRANSFORMER CHANGES ONLY ALTERNATING CURRENT

Most people all over the world use alternating current.

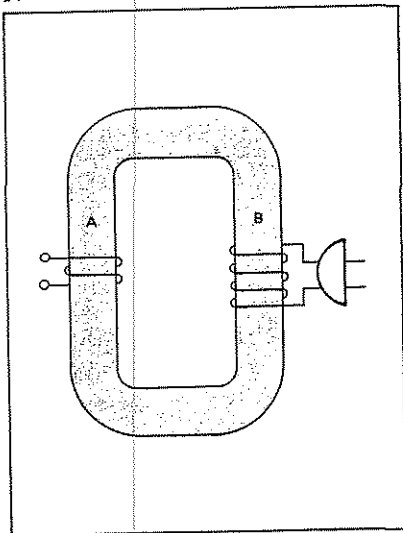
## WORKING WITH TRANSFORMERS

Figures E and F show transformers. Study each one. Then answer the questions next to the figure.

E.



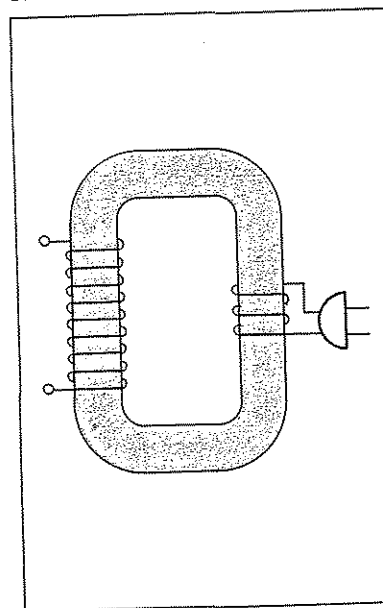
F.



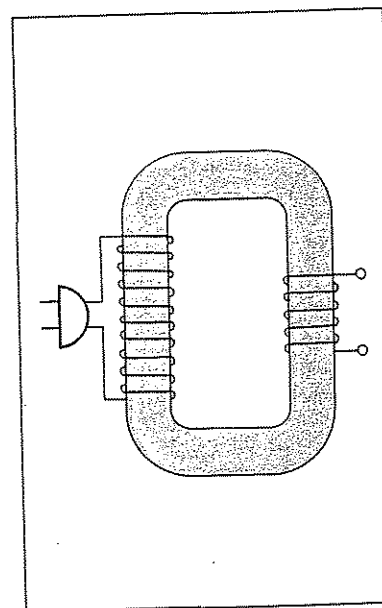
- I. 1. The primary coil is A, B.
2. The secondary coil is A, B.
3. How many turns does the primary coil have? \_\_\_\_\_
4. How many turns does the secondary coil have? \_\_\_\_\_
5. The voltage is being made \_\_\_\_\_  
stronger, weaker
6. This is a \_\_\_\_\_ transformer.  
step-up, step-down
7. If "A" has 100 volts, how many volts does "B" have? \_\_\_\_\_

- II. 1. The primary coil is A, B.
2. The secondary coil is A, B.
3. How many turns does the primary coil have? \_\_\_\_\_
4. How many turns does the secondary coil have? \_\_\_\_\_
5. This is a \_\_\_\_\_ transformer.  
step-up, step-down
6. The voltage is being made \_\_\_\_\_  
stronger, weaker
7. If "B" has 100 volts, how many volts does "A" have? \_\_\_\_\_

G.



H.



- III. 1. How many turns are there
    - a) in the primary coil? \_\_\_\_\_
    - b) in the secondary coil? \_\_\_\_\_
  2. The primary coil is connected to the \_\_\_\_\_  
electric current, appliance
  3. The secondary coil is connected to the \_\_\_\_\_  
electric current, appliance
  4. This is a \_\_\_\_\_ transformer.  
step-up, step-down
  5. The voltage is being made \_\_\_\_\_  
stronger, weaker
  6. If the primary coil has 100 volts, how many volts does the secondary coil have? \_\_\_\_\_
- IV. 1. How many turns are there
    - a) in the primary coil? \_\_\_\_\_
    - b) in the secondary coil? \_\_\_\_\_
  2. The primary coil is connected to the \_\_\_\_\_  
electric current, appliance
  3. The secondary coil is connected to the \_\_\_\_\_  
electric current, appliance
  4. This is a \_\_\_\_\_ transformer.  
step-up, step-down
  5. The voltage is being made \_\_\_\_\_  
stronger, weaker
  6. If the primary coil has 100 volts, how many volts does the secondary coil have? \_\_\_\_\_

**COMPLETING SENTENCES** Complete the sentences with the choices below. One of these may be used twice.

|                                                                           |                                                 |                                           |
|---------------------------------------------------------------------------|-------------------------------------------------|-------------------------------------------|
| two coils of insulated wire<br>stops and goes<br>step-down<br>alternating | step-up<br>direct<br>soft iron core<br>stronger | without stopping<br>weaker<br>transformer |
|---------------------------------------------------------------------------|-------------------------------------------------|-------------------------------------------|

- There are two kinds of electric currents. They are \_\_\_\_\_ current, and \_\_\_\_\_ current.
- Direct current moves \_\_\_\_\_.
- Alternating current \_\_\_\_\_ many times every second.
- A \_\_\_\_\_ changes voltage.
- A transformer works only with \_\_\_\_\_ current.
- The important parts of a transformer are: a \_\_\_\_\_ and \_\_\_\_\_.
- A step-up transformer makes voltage \_\_\_\_\_.
- A step-down transformer makes voltage \_\_\_\_\_.
- A \_\_\_\_\_ transformer has more turns in the secondary coil than in the primary coil.
- A \_\_\_\_\_ transformer has more turns in the primary coil than in the secondary coil.

**MATCHING** Match the two lists. Write the correct letter on the line next to each number.

- |                                               |                                       |
|-----------------------------------------------|---------------------------------------|
| 1. _____ step-up transformer                  | a) important parts of a transformer   |
| 2. _____ step-down transformer                | b) makes voltage stronger             |
| 3. _____ soft iron core and two sets of coils | c) stops and goes many times a second |
| 4. _____ soft iron                            | d) makes voltage weaker               |
| 5. _____ alternating current                  | e) transformer core                   |

**TRUE OR FALSE** Write T on the line next to the number if the sentence is true. Write F if the sentence is false.

- \_\_\_\_\_ A transformer changes amperes.
- \_\_\_\_\_ The core of a transformer is made of steel.
- \_\_\_\_\_ The primary coil of a transformer is connected to the appliance.
- \_\_\_\_\_ The secondary coil of a transformer is connected to the appliance.
- \_\_\_\_\_ A transformer only raises voltage.
- \_\_\_\_\_ A step-up transformer makes voltage stronger.
- \_\_\_\_\_ A step-down transformer makes voltage weaker.
- \_\_\_\_\_ Direct current starts and stops many times a second.
- \_\_\_\_\_ Alternating current starts and stops many times a second.
- \_\_\_\_\_ A transformer works only with alternating current.

**REACHING OUT** A powerhouse generator may produce more than 22,000 volts. Huge step-up transformers boost it to nearly 350,000 volts.

- Why is the voltage raised so much? \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_
- What happens to the voltage before it reaches your home? \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_



Complete the missing information. The first one has been filled in for you.

A.

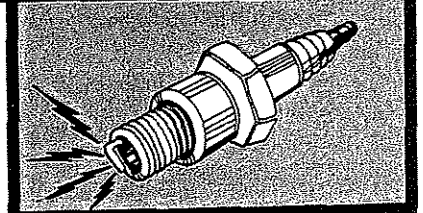
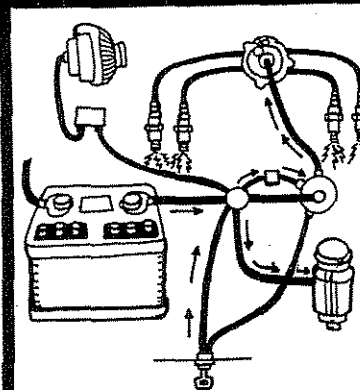
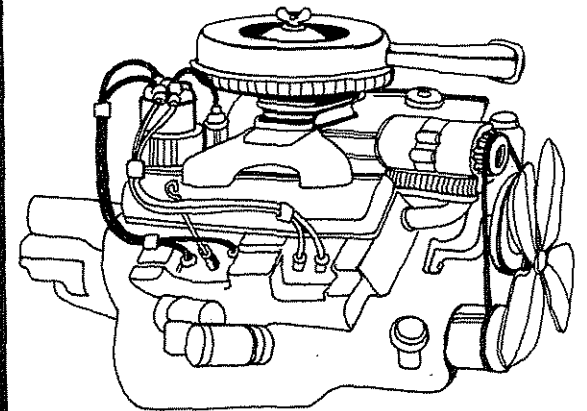
|    | Step-up Transformer | Step-down Transformer | Primary Coil Turns | Secondary Coil Turns | Primary Coil Voltage | Secondary Coil Voltage |
|----|---------------------|-----------------------|--------------------|----------------------|----------------------|------------------------|
| 1. | ✓                   |                       | 20                 | 40                   | 10                   | 20                     |
| 2. |                     |                       | 30                 |                      | 20                   | 40                     |
| 3. |                     |                       | 25                 | 5                    | 50                   |                        |
| 4. |                     |                       |                    | 10                   | 5                    | 50                     |
| 5. |                     |                       | 10                 | 2                    | 50                   |                        |

B.

|    | Step-up Transformer | Step-down Transformer | Primary Coil Turns | Secondary Coil Turns | Primary Coil Voltage | Secondary Coil Voltage |
|----|---------------------|-----------------------|--------------------|----------------------|----------------------|------------------------|
| 1. |                     |                       |                    | 60                   | 100                  | 300                    |
| 2. |                     |                       | 6                  | 24                   |                      | 200                    |
| 3. |                     |                       | 4                  |                      | 5                    | 25                     |
| 4. |                     |                       | 100                |                      | 50                   | 5                      |
| 5. |                     |                       |                    | 50                   | 300                  | 30                     |

# WHAT IS AN INDUCTION COIL?

23



induction coil: a device that increases the voltage of direct current

# AIM | What is an induction coil? 23

Cars, trucks, and buses run on gasoline. But they also need electricity. Each one needs about 20,000 volts!

Most car batteries give only 12 volts. This is not nearly strong enough.

Why not use a transformer to raise the voltage? This sounds like a good idea, but it won't work. A transformer works only with *alternating* current. And a car battery gives only *direct* current. Something else is needed.

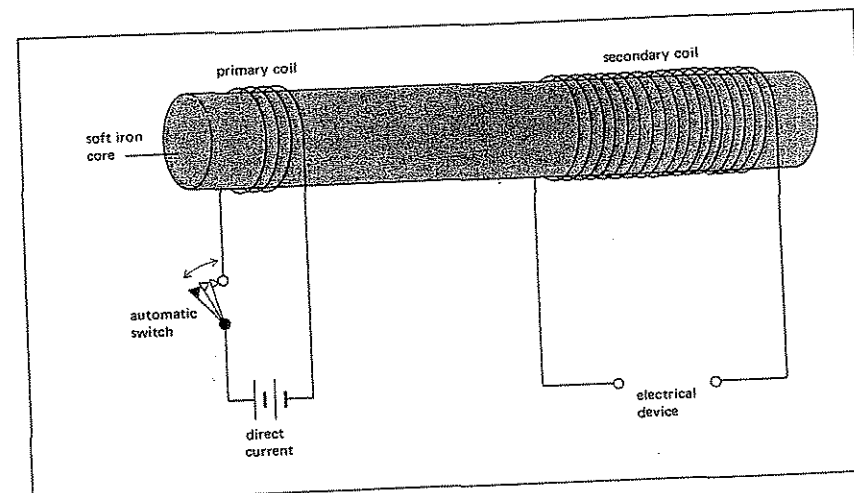
What can boost the voltage of direct current? We use an *induction coil*. An induction coil and a transformer are very much alike. Each one has

- a soft iron core, and
- two coils of insulated wire.

But there is one important difference. A transformer has no moving parts. An induction coil has an extra part that is always moving.

The extra part is a switch that opens and closes by itself many times a second. This makes the electricity stop-and-go, stop-and-go. The on-and-off switching makes the direct current act like alternating current. Because of this, the voltage can be changed.

The induction coil in a car can boost the 12 volts of the battery to 20,000 volts.



A. AN INDUCTION COIL

## COMPLETING SENTENCES

Complete the sentences with the words below. Two of these words may be used three times.

direct current  
induction coil  
alternating

alternating current  
direct

automatic switch  
transformer

1. There are two kinds of electricity; \_\_\_\_\_ current, and \_\_\_\_\_ current.
2. DC stands for \_\_\_\_\_.
3. AC stands for \_\_\_\_\_.
4. Electricity in schools and homes is usually \_\_\_\_\_ current.
5. \_\_\_\_\_ current moves without stopping.
6. \_\_\_\_\_ current starts and stops many times every second.
7. A \_\_\_\_\_ changes the voltage of alternating current.
8. An \_\_\_\_\_ changes the voltage of direct current.
9. Batteries give only \_\_\_\_\_ current.
10. The part that an induction coil has that a transformer does not have is an \_\_\_\_\_.

**THROW ONE OUT** In each of the following sets of terms, one of the terms does not belong. Circle that term.

1. AC DC induction coil
2. AC DC home
3. toy electric trains transformer induction coil
4. more primary turns more secondary turns steps-up voltage
5. most used AC DC

**WORD SEARCH** The words in the list are hidden in the group of letters. Try to find each word. Draw a line around the word. The spelling may go in any direction: up-and-down, across, or diagonally.

NORTH  
SOUTH  
INDUCTION  
CORE  
CURRENT  
BATTERY  
WIRE  
COIL

|   |   |   |   |   |   |   |   |   |   |
|---|---|---|---|---|---|---|---|---|---|
| H | S | O | E | B | C | U | T | N | H |
| P | D | E | C | A | H | T | U | O | S |
| W | N | O | I | T | C | U | D | N | I |
| R | I | W | E | T | O | T | N | O | W |
| L | N | R | I | E | R | S | U | R | H |
| W | C | U | R | R | E | N | T | T | O |
| C | I | E | W | Y | E | I | E | H | Y |

**REACHING OUT** An induction coil can make a flashlight burn brighter. Why is it not used?

## WHAT IS HEAT?



# AIM | What is heat?

24

Here is a trick question—Does an ice cube have heat? Think carefully! The answer is YES! An ice cube does have heat. It has less heat than water does. But it still has heat. All matter has heat. Some kinds of matter have more heat than other kinds.

## WHAT IS HEAT?

Heat is a form of energy.

Heat is the energy of vibrating molecules — and molecules are always vibrating. This means that all matter has heat.

How hot an object is depends on how fast its molecules vibrate. The faster the molecules vibrate, the hotter the object is.

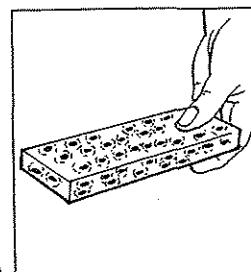
## WHERE DOES HEAT COME FROM?

The sun provides most of our heat. The sun warms our earth. It makes plants and trees grow. Without the sun, we would have no food. And we need food to live.

Burning fuel provides some heat. Coal, oil, gas, and wood are some fuels that we burn. But without the sun, these fuels would not have formed.

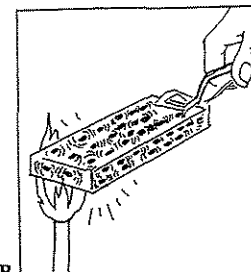
Rubbing—or friction—also provides heat. Most heat that comes from friction is not wanted. For example, heat from friction can ruin machinery. Oil and grease help reduce friction.

## LEARNING ABOUT HEAT



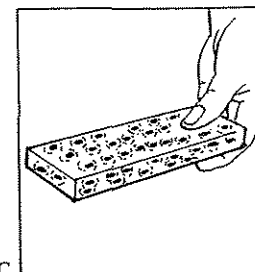
A.

Molecules are always vibrating.



B.

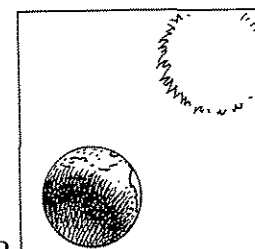
Heat makes molecules vibrate faster.



C.

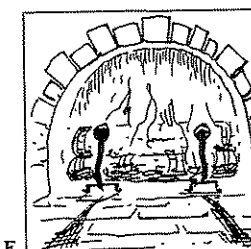
When matter cools, its molecules vibrate slower.

## SOURCES OF HEAT



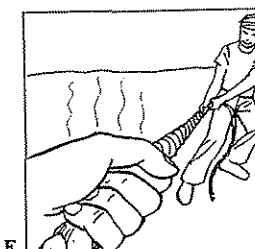
D.

the sun



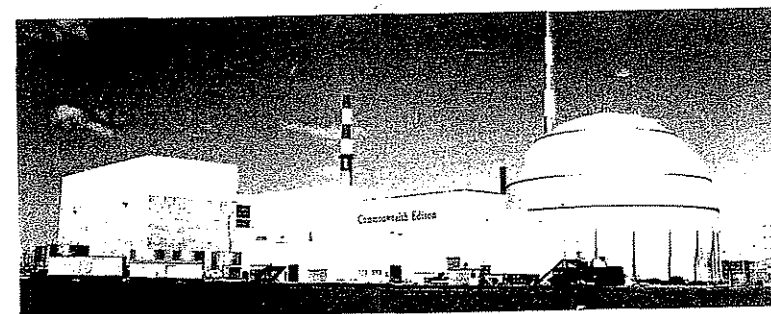
E.

burning fuel



F.

friction

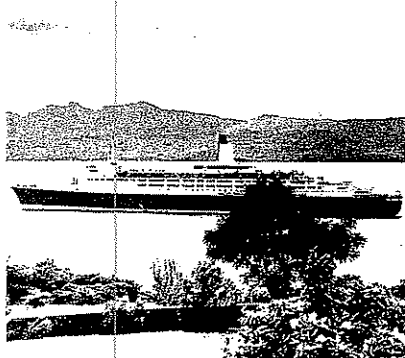


The atom can give off a tremendous amount of heat. We are just learning how to use this heat.

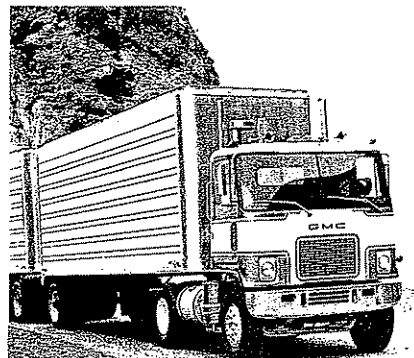
In atomic (nuclear) power plants, certain kinds of atoms are bombarded and smashed. They give up energy in the form of heat. This heat changes water to steam. The steam turns the coils in generators, which produce electricity.

## ENERGY CAN MAKE THINGS MOVE

There are many kinds of energy. Heat is one kind of energy. Heat can make things move.



A.

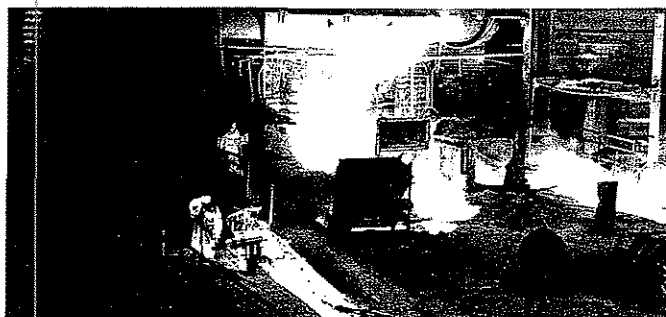


B.

Heat moves ocean liners, Diesel trucks—even your family car.

How does this happen?

1. Ocean liners, Diesel trucks, and automobile engines burn fuel.
2. Fuel has stored chemical energy. The chemical energy changes to heat energy.
3. The high temperature causes great pressure. The pressure causes movement.



C.

Heat has thousands of other uses too. For example, we use heat to warm our homes and to cook our food. Doctors use heat to kill germs. Heat is used to make metal products.

4. Heat is one form of energy. What other form of energy did you learn about in this book? \_\_\_\_\_

**COMPLETING SENTENCES** Complete the sentences with the choices below. Three of these may be used twice.

electricity  
sun  
vibrating

more  
move  
friction

vibrating molecules  
heat  
less

1. Energy can make things \_\_\_\_\_.
2. Two kinds of energy are \_\_\_\_\_ and \_\_\_\_\_.
3. Heat is caused by \_\_\_\_\_.
4. All matter has \_\_\_\_\_ because molecules are always \_\_\_\_\_.
5. Warm matter has \_\_\_\_\_ heat than cold matter.
6. Cool matter has \_\_\_\_\_ heat than warm matter.
7. The faster molecules vibrate, the \_\_\_\_\_ heat they give off.
8. The slower molecules vibrate, the \_\_\_\_\_ heat they give off.
9. Most heat comes from the \_\_\_\_\_.
10. Rubbing produces heat. Another name for rubbing is \_\_\_\_\_.

**TRUE OR FALSE** Write T on the line next to the number if the sentence is true.  
Write F if the sentence is false.

1. \_\_\_\_\_ All molecules vibrate.
2. \_\_\_\_\_ Molecules always vibrate at the same speed.
3. \_\_\_\_\_ The faster molecules vibrate, the less heat they give off.
4. \_\_\_\_\_ Most of our heat comes from the moon.
5. \_\_\_\_\_ Coal, wood, oil, and gas are fuels.
6. \_\_\_\_\_ Without the sun, we would have no coal, wood, oil, or gas.
7. \_\_\_\_\_ A piece of dust has heat.
8. \_\_\_\_\_ A flame always gives off heat.
9. \_\_\_\_\_ Heat always gives off a flame.

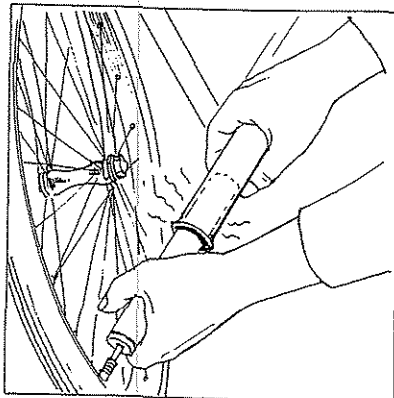
**MATCHING** Match the two lists. Write the correct letter on the line next to each number.

- |                               |                              |
|-------------------------------|------------------------------|
| 1. _____ friction             | a) gives us most of our heat |
| 2. _____ sun                  | b) examples of fuel          |
| 3. _____ vibrating molecules  | c) can make things move      |
| 4. _____ energy               | d) rubbing                   |
| 5. _____ coal, wood, oil, gas | e) cause all heat            |

**WORD SCRAMBLE** Unscramble each of the following to form a word or term that you have read in this Aim.

1. REGYEN \_\_\_\_\_
2. LUFE \_\_\_\_\_
3. TROCINIF \_\_\_\_\_
4. TEAH \_\_\_\_\_
5. BUNGBIR \_\_\_\_\_

### REACHING OUT



The boy is pumping air into the bike tire.

The pump is getting hot.

Can you explain why?

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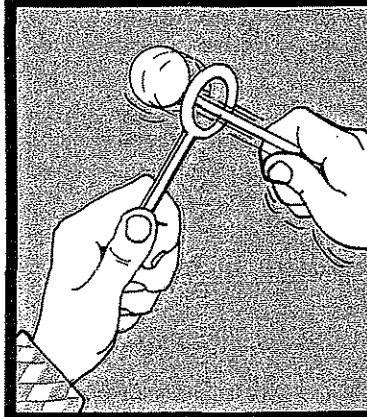
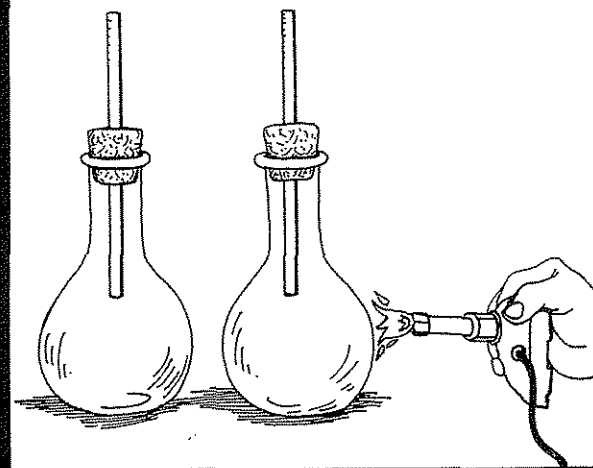
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## HOW DOES HEAT CHANGE THE SIZE OF MATTER?

25



**expand:** to become larger  
**contract:** to become smaller

AIM  
25

HEAT MAKES THINGS LARGER.

When matter cools, the opposite happens. The molecules vibrate slower. Now they need less room. They move together. This makes the matter smaller. It contracts.

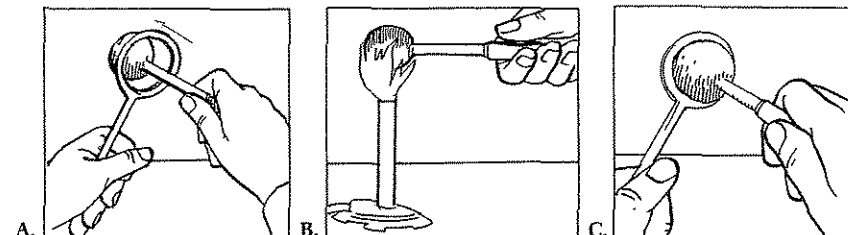
Most matter expands when heated  
and  
contracts when cooled.

Temperature is always changing—growing warmer or cooler. The size of matter is always changing, too. Usually, matter expands or contracts only slightly. Size changes very little. Then it is not important. But sometimes, size changes a lot. Then it is very important. For example, when heat expands a roadway, the roadway can buckle. Heat expansion can make drawbridges stick.

Different kinds of matter expand at different rates. Some matter expands a great deal. Other matter expands only a little.

1. How do heat and cold change the size of a *solid*?

What You Need    brass ring  
                          brass ball that "just" fits through the ring  
                          Bunsen burner  
                          cold water



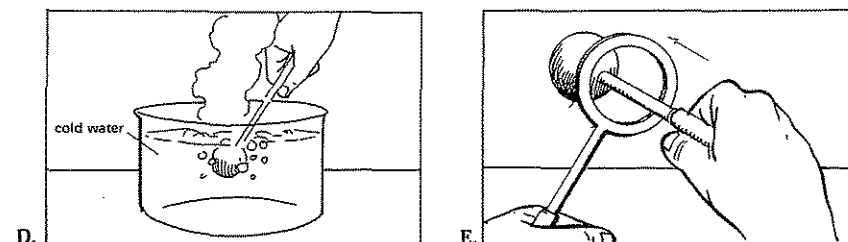
### How To Do the Experiment

1. Pass the brass ball through the ring. Notice the close fit (Figure A).
2. Heat the ball over the flame for about one minute (Figure B).
3. Now try to pass the ball through the ring (Figure C).

### What You Saw; What You Learned

4. The heated ball \_\_\_\_\_ pass through the ring.  
did, did not
5. The heat made the ball \_\_\_\_\_.  
smaller, larger
6. The ball \_\_\_\_\_.  
expanded, contracted

## Next Steps



7. Dip the heated ball into the cold water(Figure D).
8. Try to pass the ball through the ring(Figure E).

### What You Saw; What You Learned

9. After the ball cooled, it \_\_\_\_\_ pass through the ring.  
did, did not
10. The cold water made the ball \_\_\_\_\_.  
smaller, larger

11. The ball \_\_\_\_\_.  
expanded, contracted

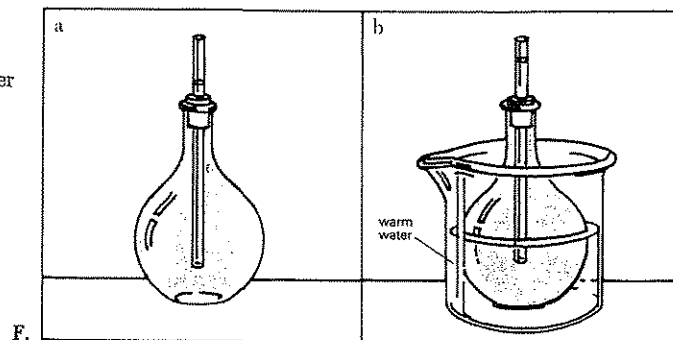
### Conclusions

12. Heat \_\_\_\_\_ a solid.  
expands, contracts
13. Cold \_\_\_\_\_ a solid.  
expands, contracts

### II. How do heat and cold change the size of a liquid?

#### What You Need

glass bottle  
cold colored water  
one-holed  
stopper with  
glass tube  
warm water  
large beaker



#### How To Do the Experiment

1. Put cold colored water in the bottle. Cap with cork. Put glass tube through hole of cork and into the water.
2. Heat the bottle gently by placing it in a warm-water bath (Figure F). Then take the bottle out of the warm water. [Watch the water level in the tube].

### What You Saw; What You Learned

3. When you heated the bottle, the water in the tube moved \_\_\_\_\_.  
up, down
4. The water rose because it \_\_\_\_\_.  
expanded, contracted

5. When you took away the heat, the water became \_\_\_\_\_.  
cooler, warmer
6. The water moved \_\_\_\_\_ in the tube.  
up, down
7. The water moved down because it \_\_\_\_\_.  
expanded, contracted

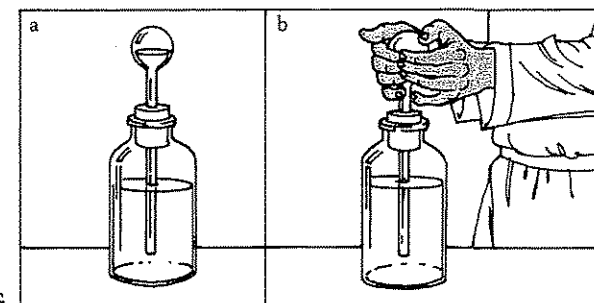
### Conclusions

8. When a liquid is heated it \_\_\_\_\_.  
expands, contracts
9. When a liquid cools, it \_\_\_\_\_.  
expands, contracts

### III. How do heat and cold change the size of gas?

#### What You Need

Pyrex bottle  
cold colored water  
one-holed stopper with  
bulb-end glass tube



#### What To Do

1. Set up equipment as shown (Figure G).
2. Heat the bulb gently by wrapping your hands around it (Figure G). Keep your hands around the bulb for one minute. Then take your hands away. (Watch the water level in the tube).

### What You Saw; What You Learned

3. There is mostly \_\_\_\_\_ in the bulb.  
water, gas
4. When you heated the bulb, the gas took up \_\_\_\_\_ room.  
more, less
5. The gas \_\_\_\_\_.  
expanded, contracted
6. The expanded gas \_\_\_\_\_.  
made the water rise, pushed the water down



7. a) When you took away the heat, the gas \_\_\_\_\_  
became warmer, cooled a bit
- b) The gas \_\_\_\_\_  
expanded, contracted
- c) The gas pressed on the water with \_\_\_\_\_ force.  
more, less
- d) The water in the tube moved \_\_\_\_\_  
up, down

#### Conclusions

8. When a gas is heated, it \_\_\_\_\_  
expands, contracts
9. When a gas cools, it \_\_\_\_\_  
expands, contracts

You have learned that matter expands when heated and contracts when cooled. But there are exceptions.

One exception is water.

When water is cooled to make ice, it becomes bigger—it expands.

**MATCHING** Match the two lists. Write the correct letter on the line next to each number.

- |          |                     |                                   |
|----------|---------------------|-----------------------------------|
| 1. _____ | molecules           | a) makes molecules vibrate faster |
| 2. _____ | heat                | b) sun                            |
| 3. _____ | cold                | c) always vibrating               |
| 4. _____ | states of matter    | d) solids, liquids, gases         |
| 5. _____ | source of most heat | e) makes molecules vibrate slower |

#### COMPLETING SENTENCES

Complete the sentences with the choices below. Two of these may be used twice.

expand  
contracts  
heat

shake very rapidly  
become smaller  
less

more  
become larger  
vibrating

- Vibrate means to \_\_\_\_\_.
- Molecules are always \_\_\_\_\_.
- Vibrating molecules give off \_\_\_\_\_.
- When molecules vibrate faster, they give off \_\_\_\_\_ heat.
- When molecules vibrate faster, they need \_\_\_\_\_ room.
- Heat makes matter \_\_\_\_\_ in size.  
(one word)
- When molecules vibrate slower, they give off \_\_\_\_\_ heat.
- When molecules vibrate slower, they need \_\_\_\_\_ room.
- Matter that cools \_\_\_\_\_ in size.  
(one word)
- Expand means \_\_\_\_\_; contract means \_\_\_\_\_.

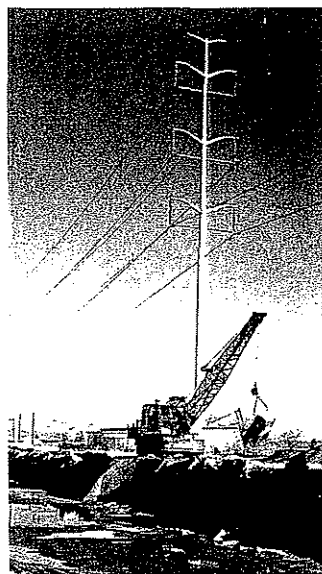
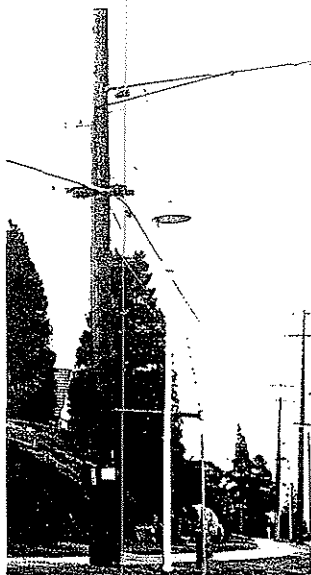
#### TRUE OR FALSE

Write T on the line next to the number if the sentence is true. Write F if the sentence is false.

- \_\_\_\_\_ All molecules vibrate.
- \_\_\_\_\_ The slower molecules vibrate, the more heat they give off.
- \_\_\_\_\_ Matter contracts when it is heated.
- \_\_\_\_\_ Matter contracts when it is cooled.
- \_\_\_\_\_ All matter expands and contracts the same amount.

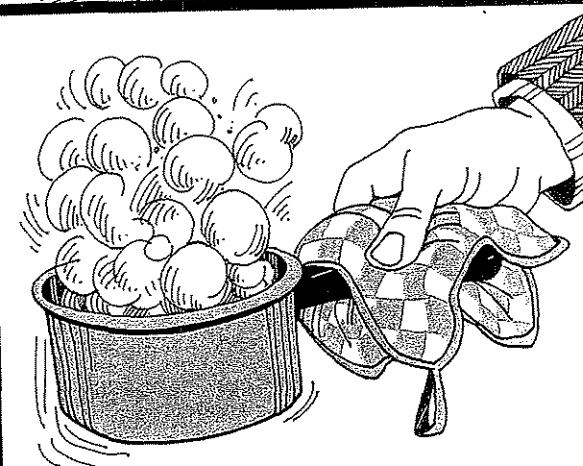
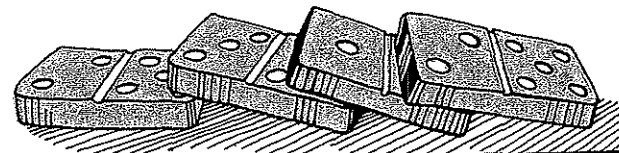
## REACHING OUT

1. Why are there spaces along railroad tracks? \_\_\_\_\_
2. Why do steel bridges have rollers or joints? \_\_\_\_\_
3. Why are overhead wires hung with a slight sag in the summertime? \_\_\_\_\_
4. Why are the same wires hung tightly during the wintertime? \_\_\_\_\_
5. Why are sidewalks and roads made with "cracks"? \_\_\_\_\_
6. Why are liquids never filled to the very top of a bottle? \_\_\_\_\_



## HOW DOES HEAT MOVE THROUGH SOLIDS?

26



conduction: the way heat moves through solids

# AIM | How does heat move 26 | through solids?

Did you ever grab a hot pan handle? The handle was hot even though it wasn't over the burner. How did the heat move to the handle?

First, the bottom of the pan became hot. The molecules there vibrated faster and faster. As they vibrated, they bumped into other molecules. Then, the other molecules became hot, vibrated faster, and bumped into other molecules.

This happened over and over again. As it did, the heat moved farther along. Soon, the entire pan was hot.

The passing along of heat from molecule to molecule is called *conduction* [kon DUCK shun]. Only solids move heat by conduction.

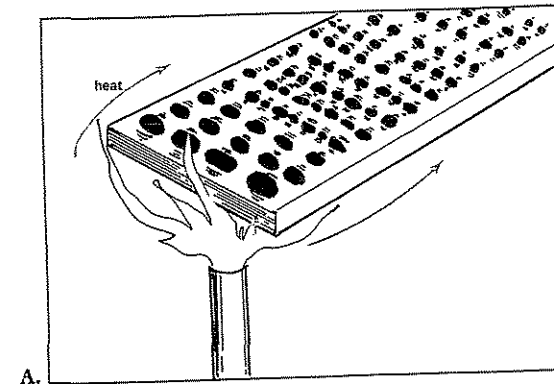
In solids, the molecules are packed very close together. They cannot move from place to place. The molecules just vibrate faster and faster when a solid is heated.

All solids conduct heat. Some conduct heat much better than others. Solids that conduct heat well are called good conductors. Metals are the best heat conductors.

Wood, glass, and plastics do not conduct heat well. They are poor conductors. Poor conductors are used as insulators [IN soo late erz]. Insulators keep heat from moving where it is not wanted. They keep things from becoming too hot or too cold. If the handle of the pan is covered by an insulator, you won't burn your hand.

Insulators protect us from heat and cold. They keep us comfortable.

## WHAT DO THE PICTURES SHOW?



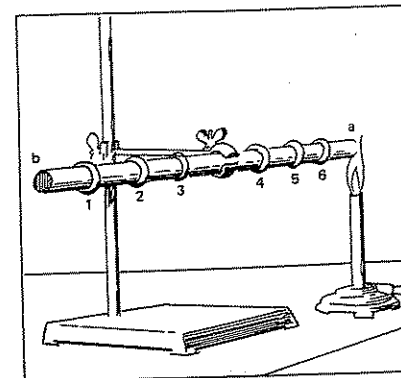
Look at each picture. Then answer the questions for Figures B and C.

Heat moves through solids by conduction.

In conduction, heat is passed along from molecule to molecule.

Figure B shows six rings of wax on a metal rod. The flame has just been placed under the rod.

B.



1. Which wax ring will melt first?  
\_\_\_\_\_
2. Which wax ring will melt last?  
\_\_\_\_\_
3. Which end gets hot first? \_\_\_\_\_
4. Which end gets hot last? \_\_\_\_\_
5. What do we call the way heat moves in solids? \_\_\_\_\_

C.

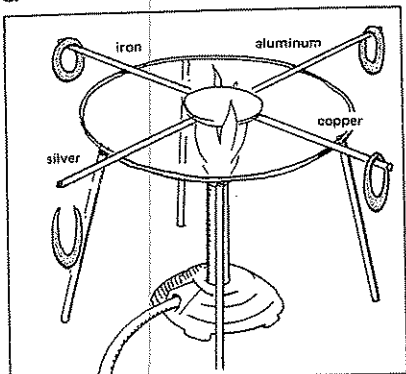


Figure C shows wax rings at same distance from flame.

6. Are all the wax rings melting at the same time? \_\_\_\_\_
7. Are the rods made of the same metal? \_\_\_\_\_
8. a) Which one of these rods conducts heat best? \_\_\_\_\_  
b) How do you know?  
a) The wax melts first.  
b) The wax melts last.

9. a) Which one conducts heat slowest? \_\_\_\_\_  
b) How do you know?  
a) The wax melts first. b) The wax melts last.

10. This experiment shows that conduction is \_\_\_\_\_  
the same for all solids, different for different solids

**MATCHING** Match the two lists. Write the correct letter on the line next to each number.

- |                              |                                    |
|------------------------------|------------------------------------|
| 1. _____ insulate            | a) good heat conductors            |
| 2. _____ metals              | b) give off heat energy            |
| 3. _____ conduction          | c) poor heat conductors            |
| 4. _____ plastics and wood   | d) to protect against heat or cold |
| 5. _____ vibrating molecules | e) the way heat moves in solids    |

**COMPLETING SENTENCES** Complete the sentences with the choices below.

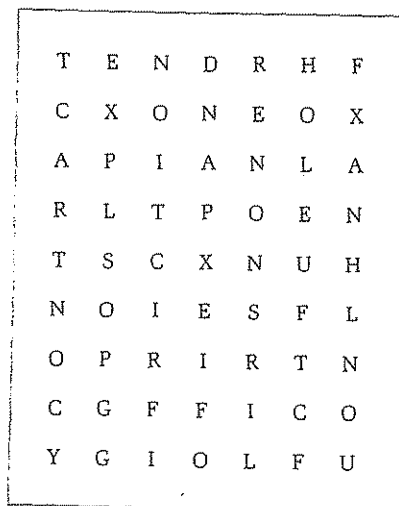
- |            |        |        |
|------------|--------|--------|
| insulator  | faster | solids |
| vibrate    | metals | heat   |
| conduction | bump   | do not |
| protect    | better |        |
1. Heat makes molecules vibrate \_\_\_\_\_.
  2. The faster molecules vibrate, the more they \_\_\_\_\_ into other molecules.
  3. When molecules hit other molecules, the other molecules \_\_\_\_\_ faster and give off more \_\_\_\_\_.
  4. The passing of heat from molecule to molecule is called \_\_\_\_\_.
  5. Only \_\_\_\_\_ move heat by conduction.
  6. Molecules of solids \_\_\_\_\_ move from place to place.
  7. The best conductors of heat are \_\_\_\_\_.
  8. Some metals are \_\_\_\_\_ heat conductors than others.
  9. A poor conductor is called an \_\_\_\_\_.
  10. The job of an insulator is to \_\_\_\_\_ against unwanted heat.

**TRUE OR FALSE** Write T on the line next to the number if the sentence is true. Write F if the sentence is false.

1. \_\_\_\_\_ All matter has heat.
2. \_\_\_\_\_ Heat can move from place to place.
3. \_\_\_\_\_ Molecules vibrate slower when they are heated.
4. \_\_\_\_\_ Heat moves through liquids and gases by conduction.
5. \_\_\_\_\_ Conduction moves heat from molecule to molecule.
6. \_\_\_\_\_ In conduction, molecules move from place to place.
7. \_\_\_\_\_ All solids are good conductors of heat.
8. \_\_\_\_\_ Metals are good conductors of heat.
9. \_\_\_\_\_ Metals are good insulators of heat.
10. \_\_\_\_\_ Wood and plastics are good insulators of heat.

**WORD SEARCH** The words in this list are hidden in the groups of letters. Try to find each word. Draw a line around each word. The spelling may go in any direction: up-and-down, across, or diagonally.

HEAT  
SUN  
FRICTION  
ENERGY  
FUEL  
EXPAND  
CONTRACT



**REACHING OUT** How can you make molecules of metals move from place to place?

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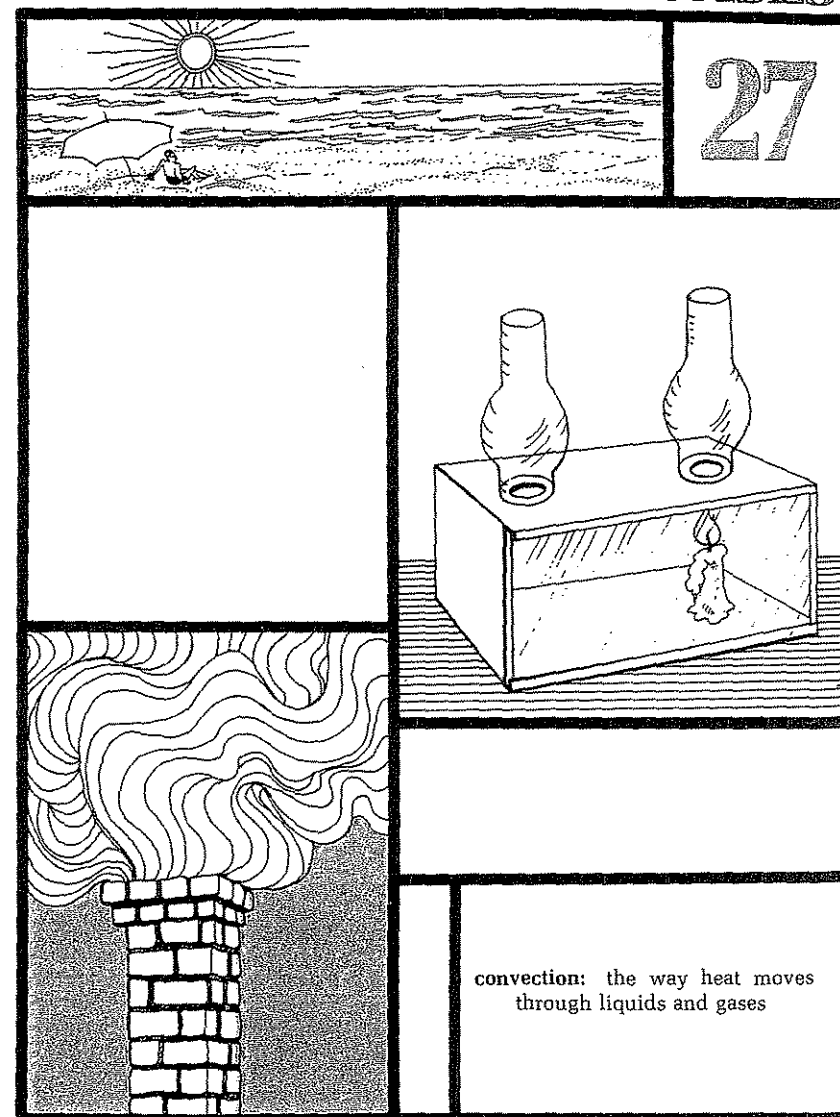


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# HOW DOES HEAT MOVE THROUGH LIQUIDS AND GASES?



# AIM How does heat move 27 through liquids and gases?

You have learned that the molecules of solids are packed very close together. When a solid is heated, its molecules vibrate faster, but they cannot move from place to place.

The molecules of liquids and gases are not tightly packed. There are spaces between the molecules. This means that the molecules can move from place to place.

What happens when a liquid or gas is heated?

Follow this explanation step-by-step. (Also look at Figure D.)

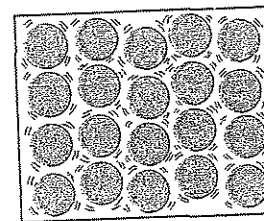
- The molecules closest to the heat get hot first. They vibrate faster. They also move. They move away from the heat.
- Cooler molecules move in and take their place.
- The cooler molecules are heated. Then they move away.
- Other molecules move in to take their place.

This happens over and over again. Little by little, all the molecules in the gas or liquid are heated. The molecules that were heated first cool a bit. Then they move back toward the heat and are heated again. This happens over and over—heating, cooling, and then re-heating.

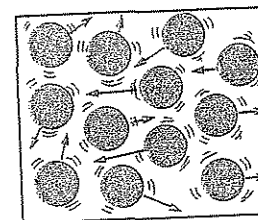
The passing along of heat by moving molecules is called convection [kon VECK shun]. Only gases and liquids are heated by convection.

## WHAT DO THE DIAGRAMS SHOW?

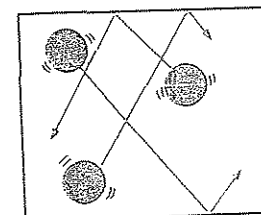
The diagrams below show atoms of solids, liquids, and gases. Study the diagrams. Then answer the questions below.



A.  
ATOMS OF  
SOLIDS



B.  
ATOMS OF  
LIQUIDS

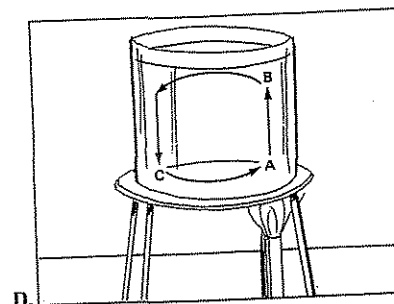


C.  
ATOMS OF  
GASES

Which atoms

1. are closest together? \_\_\_\_\_
2. are farthest apart? \_\_\_\_\_
3. vibrate? \_\_\_\_\_
4. do not vibrate? \_\_\_\_\_
5. do not move from place to place? \_\_\_\_\_
6. do move from place to place? \_\_\_\_\_
7. move the most? \_\_\_\_\_
8. become hot by conduction? \_\_\_\_\_
9. become hot by convection? \_\_\_\_\_

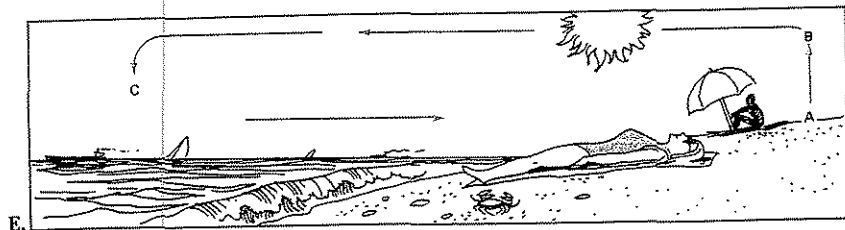
## STUDYING CONVECTION IN A LIQUID



D.

1. The water at A is heated first. It rises to B.
2. As it rises, it cools a bit.
3. The cooled water turns around and drops to C. Then it moves to A again. Here it is reheated.
4. Now, start again with step 1. Repeat the steps over and over and over again.

## STUDYING CONVECTION IN GASES

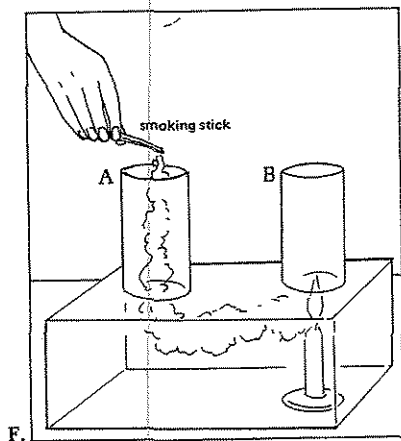


- I. 1. The sun heats the air. The air over the ground, A, becomes warm first. It rises to B.
2. As it rises, it cools.
3. The cooler air turns around and drops to C. It then moves to A again. Here it is reheated.
4. Now start again with step 1. Repeat the steps over and over again.

When air from A rises, other air from C moves in to take its place. What do you call this kind of moving air? \_\_\_\_\_ (Take a guess. You know this term. You use it often.)

II. This is called a convection box.

The burning candle makes air move out of one chimney and into the other.



1. Which air is warmer? The air in chimney \_\_\_\_\_ A, B.
2. Which air is cooler? The air in chimney \_\_\_\_\_ A, B.
3. Air in chimney B is \_\_\_\_\_ rising, falling.
4. Air in chimney A is \_\_\_\_\_ rising, falling.
5. Air is moving from \_\_\_\_\_ A to B, B to A.
6. Draw arrows to show how the air moves.

## COMPLETING SENTENCES

Complete the sentences with the choices below.

take their place  
convection  
cannot  
sun

conduction  
more  
solids  
move away

gases  
friction  
vibrating

1. Molecules of \_\_\_\_\_ are closest together.
2. Molecules of \_\_\_\_\_ are farthest apart.
3. Heat moves through solids by a method called \_\_\_\_\_.
4. Heat moves through liquids and gases by a method called \_\_\_\_\_.
5. Heat is caused by \_\_\_\_\_ molecules.
6. The faster molecules vibrate, the \_\_\_\_\_ heat they give off.
7. In conduction, vibrating molecules \_\_\_\_\_ move from place to place.
8. In convection, heated molecules \_\_\_\_\_ and other molecules \_\_\_\_\_.
9. Almost all of our heat energy comes from the \_\_\_\_\_.
10. Another name for rubbing is \_\_\_\_\_.

## MATCHING

Match the two lists. Write the correct letter on the line next to each number.

1. \_\_\_\_\_ conduction
2. \_\_\_\_\_ convection
3. \_\_\_\_\_ solids
4. \_\_\_\_\_ gases
5. \_\_\_\_\_ sun

- a) molecules farthest apart
- b) the way heat moves through solids
- c) source of most of our energy
- d) the way heat moves through liquids and gases
- e) molecules closest together

TRUE OR FALSE Write T on the line next to the number if the sentence is true.  
Write F if the sentence is false.

1. \_\_\_\_\_ Only molecules of solids vibrate.
2. \_\_\_\_\_ Molecules of solids can move from place to place.
3. \_\_\_\_\_ Molecules of liquids and gases can move from place to place.
4. \_\_\_\_\_ Molecules of liquids are closer together than molecules of gases.
5. \_\_\_\_\_ Molecules of solids are closer together than molecules of liquids.
6. \_\_\_\_\_ Heat makes molecules vibrate faster.
7. \_\_\_\_\_ The faster molecules vibrate, the more heat they give off.
8. \_\_\_\_\_ Cooling makes molecules vibrate faster.
9. \_\_\_\_\_ All molecules vibrate at the same speed.
10. \_\_\_\_\_ All our energy comes from the sun.

REACHING OUT Why should a room have a window open from the top and the bottom?

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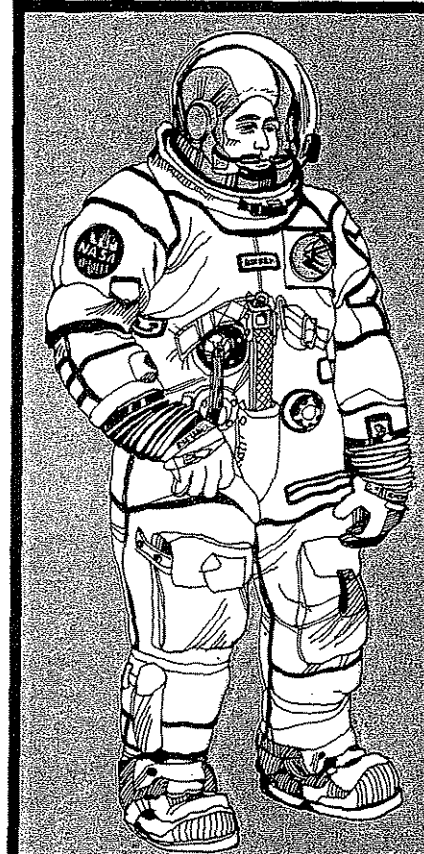
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## HOW DOES THE SUN'S HEAT REACH US?

28



radiation: the way heat moves through empty space  
reflect: to bounce off  
absorb: to take in



# AIM How does the sun's heat reach us?

28

Can heat move where there is no matter?

You have learned that in conduction and convection, heat is carried by vibrating molecules. And molecules are matter.

Most of our heat comes from the sun. And the sun is 150 million kilometers (93 million miles) away. Most of this great distance is empty space. There are no molecules there.

Then, how does the heat reach us?

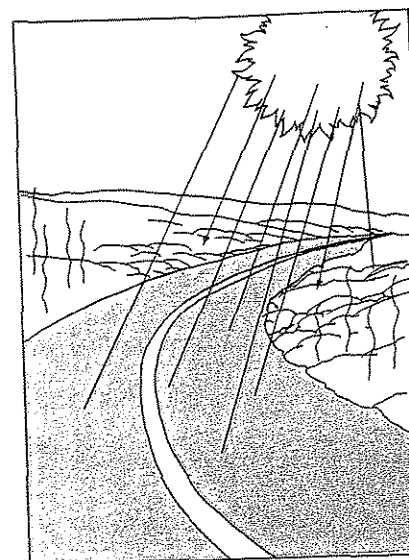
There is a third way that heat travels. Heat moves through empty space by radiation. Radiation needs no molecules. The sun's heat reaches us by radiation.

When the sun's heat reaches the earth, two things happen.

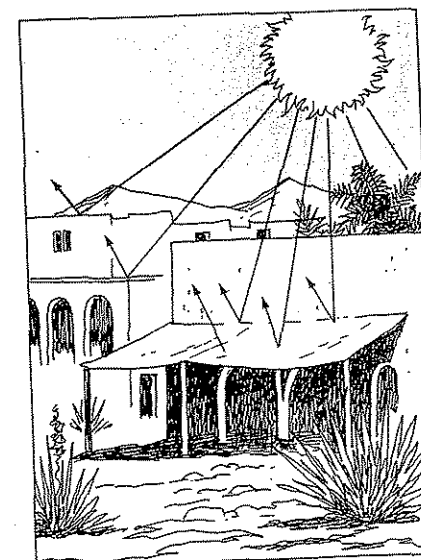
1. Part of the heat bounces off the surface of the earth. It is reflected.
2. Part of the heat is taken in by the air, water, and land. It is absorbed. Matter warms up when it absorbs heat energy.

Radiation does not come only from outer space. Heat from a flame or a hot object reaches us by radiation. We would feel some of the heat even if there were no molecules of air around us.

## COLOR AFFECTS HOW MUCH OF THE SUN'S ENERGY AN OBJECT ABSORBS OR REFLECTS



A.



B.

Dark colors absorb heat.

Light colors reflect heat.

1. This means that . . .
  - a) dark colors \_\_\_\_\_ than light colors.  
become warmer, stay cooler
  - b) light colors \_\_\_\_\_ than dark colors.  
become warmer, stay cooler
2. In the winter, \_\_\_\_\_ colored clothing helps keep us warm.  
light, dark
3. In the summer, \_\_\_\_\_ colored clothing helps keep us cool.  
light, dark
4. Would you wear dark or light clothing if you lived near a desert or near the equator?  
\_\_\_\_\_
5. Would you wear dark or light clothing if you lived in the the far north or far south?  
\_\_\_\_\_

**COMPLETING SENTENCES** Complete the sentences with the choices below. One of these may be used twice.

|            |             |           |
|------------|-------------|-----------|
| reflect    | conduction  | matter    |
| radiation  | absorbed    | absorb    |
| convection | empty space | reflected |

- Heat moves through solids by a method called \_\_\_\_\_.
- Heat moves through liquids and gases by a method called \_\_\_\_\_.
- In conduction and convection, heat moves through \_\_\_\_\_.
- Between the sun and the earth there is mostly \_\_\_\_\_.
- Energy that can move through empty space is called \_\_\_\_\_.
- The sun's energy reaches us by a method called \_\_\_\_\_.
- Energy that is taken in is "\_\_\_\_\_".
- Matter that bounces off is "\_\_\_\_\_".
- Dark colors \_\_\_\_\_ heat.
- Light colors \_\_\_\_\_ heat.

**THROW ONE OUT!** In each of the following sets of terms, one of the terms does not belong. Circle that term.

- conduction    convection    atmosphere
- radiation    convection    outer space
- dark colors    light colors    absorb
- dark colors    light colors    reflect
- molecules    conduction    radiation

**CHOOSE ONE** Choose the correct word or term for each statement. Write your choice in the space.

- Heat moves through solids by \_\_\_\_\_  
conduction, convection, radiation
- Heat moves through liquids by \_\_\_\_\_  
conduction, convection, radiation
- Heat moves through gases by \_\_\_\_\_  
conduction, convection, radiation
- Heat moves through outer space by \_\_\_\_\_  
conduction, convection, radiation
- Conduction \_\_\_\_\_ need molecules.  
does, does not
- Convection \_\_\_\_\_ need molecules.  
does, does not
- Radiation \_\_\_\_\_ need molecules.  
does, does not
- Heat that reaches the earth is \_\_\_\_\_  
absorbed only, reflected only, absorbed and reflected
- Dark colors mostly \_\_\_\_\_ heat.  
absorb, reflect
- Light colors mostly \_\_\_\_\_ heat.  
absorb, reflect

**WORD SCRAMBLE** Unscramble each of the following to form a word or term that you have read in this Aim.

- DAITRONIA \_\_\_\_\_
- SCEAP \_\_\_\_\_
- BRASBO \_\_\_\_\_
- FLERTCE \_\_\_\_\_
- MEYPT \_\_\_\_\_

## CONDUCTION, CONVECTION, OR RADIATION?

Fill in each blank space with one or more of these terms.

1. The way heat moves through liquids and gases \_\_\_\_\_
2. The way heat reaches the moon \_\_\_\_\_
3. The way heat moves through solids \_\_\_\_\_
4. Heat-movement that needs no molecules \_\_\_\_\_
5. Heat-movements that need molecules \_\_\_\_\_

**MATCHING** Match the two lists. Write the correct letter on the line next to each number.

- |          |                           |                       |
|----------|---------------------------|-----------------------|
| 1. _____ | conduction and convection | a) absorb radiation   |
| 2. _____ | radiation                 | b) always vibrating   |
| 3. _____ | dark colors               | c) need molecules     |
| 4. _____ | light colors              | d) reflect radiation  |
| 5. _____ | molecules                 | e) needs no molecules |

**REACHING OUT** How can pollution change the temperature of our planet?

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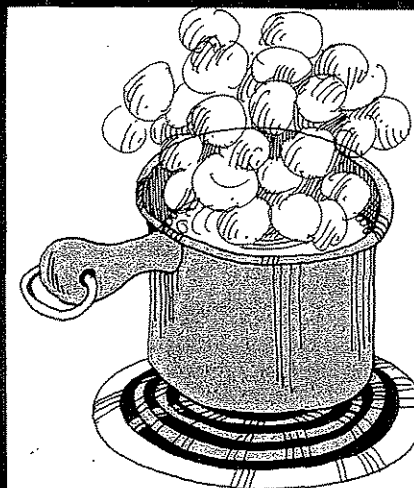
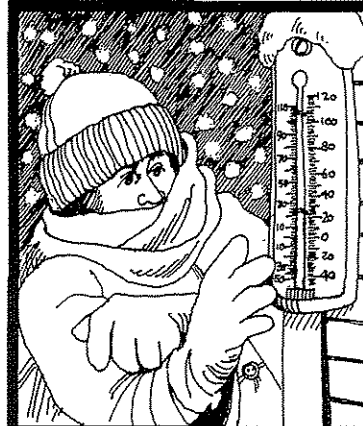
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## WHAT IS THE DIFFERENCE BETWEEN HEAT AND TEMPERATURE?

29



**temperature:** the amount of heat we feel

**heat:** the total amount of energy of a group of molecules

**calorie:** a unit to measure heat

# AIM | What is the difference between 29 | heat and temperature?

"What a hot day!"  
"Gee! It's cold!"  
"What's the temperature outside?"  
"Ma! My head feels warm!"

We often talk about heat and temperature. Are they the same? Heat and temperature are related. But they are not the same.

## TEMPERATURE

The word *temperature* is used to describe the amount of heat felt. Temperature is measured with a thermometer. Temperature is measured in degrees. We use different thermometers to measure the temperatures of our bodies, the temperature outdoors, the temperature of an oven. But the measurement is always in degrees.

Temperature depends on how fast molecules vibrate. The faster molecules vibrate, the higher the temperature. The slower they vibrate, the lower the temperature.

## HEAT

Heat is the total energy given off by all the vibrating molecules in a bit of matter.

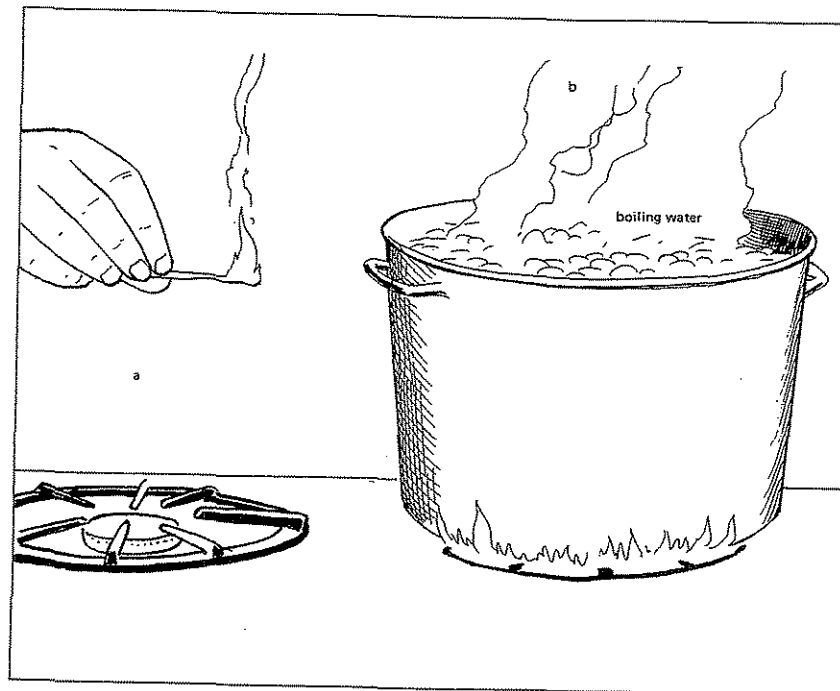
Heat depends on two things: *how fast molecules vibrate* (temperature), and *how many molecules vibrate*. That means that size affects the amount of heat. Larger things have more molecules. So if you have a large object and a small object with the same temperature, the large object will have more heat.

Heat is measured in *calories*. Have you heard that word before?

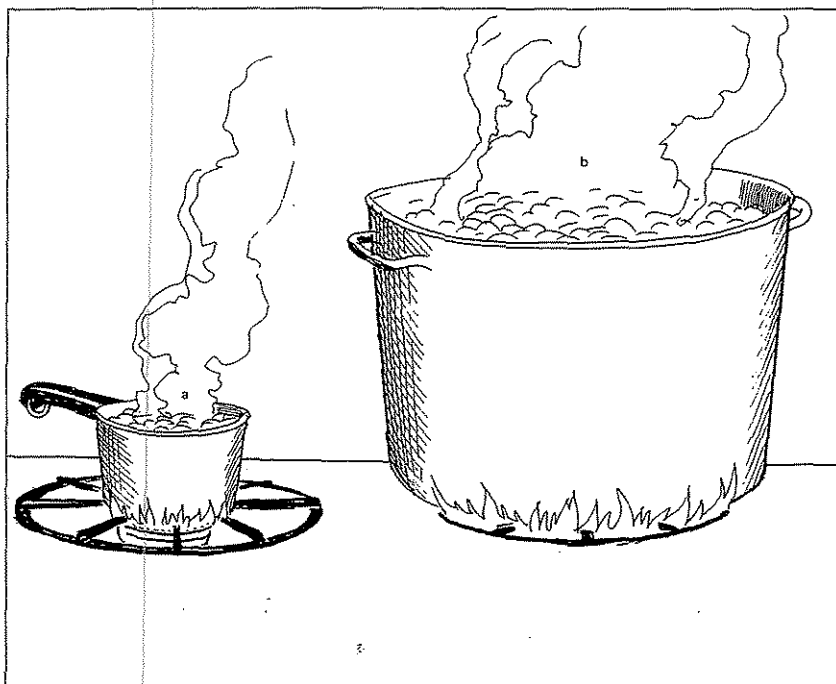
## WHAT DO THE PICTURES SHOW?

Test your understanding of temperature and heat. Study the drawings below. Then answer the questions that go with each diagram.

A.



- I. Look at Figure A. Both the match and the water are hot.  
The flame has a higher temperature than boiling water.
1. Can a single match boil this much water? \_\_\_\_\_
2. Which one do you think can melt more ice? \_\_\_\_\_  
the burning match, the boiling water
3. Which has more heat? \_\_\_\_\_  
the burning match, the boiling water
4. This shows that higher temperature \_\_\_\_\_ always mean more heat.  
does, does not
5. The boiling water has more heat because it has \_\_\_\_\_  
more molecules, a higher temperature
6. The term that describes the "feeling" of heat is \_\_\_\_\_  
calories, temperature
7. The term that describes *total heat energy* is \_\_\_\_\_  
calories, temperature



B. Both pots contain boiling water.

ii. Look at Figure B.

8. In comparing temperatures,
  - a) a is higher than b
  - b) b is higher than a
  - c) a and b are the same
9. In comparing the speed of their vibrating molecules,
  - a) a vibrates faster than b
  - b) b vibrates faster than a
  - c) a and b vibrate at the same speed
10. a) a and b \_\_\_\_\_ have the same calories.  
do, do not
  - b) Which one has fewer calories? \_\_\_\_\_ Why? \_\_\_\_\_
  - c) Which one has more calories? \_\_\_\_\_ Why? \_\_\_\_\_

**COMPLETING SENTENCES** Complete the sentences with the choices below. One of these may be used twice.

|                            |                    |                         |
|----------------------------|--------------------|-------------------------|
| less heat                  | degrees            | not                     |
| lower temperature          | related            | the number of molecules |
| expand                     | higher temperature | more heat               |
| how fast molecules vibrate | calories           |                         |

1. Heat and temperature are \_\_\_\_\_ but they are \_\_\_\_\_ the same.
2. Temperature depends upon \_\_\_\_\_.
3. Heat depends on \_\_\_\_\_ and also \_\_\_\_\_ that vibrate.
4. Faster vibrating molecules mean \_\_\_\_\_.
5. Slower vibrating molecules mean \_\_\_\_\_.
6. More vibrating molecules usually mean \_\_\_\_\_.
7. Fewer vibrating molecules usually mean \_\_\_\_\_.
8. Temperature is measured in units called \_\_\_\_\_.
9. Heat is measured in units called \_\_\_\_\_.
10. Heat makes matter \_\_\_\_\_.

**TRUE OR FALSE** Write T on the line next to the number if the sentence is true. Write F if the sentence is false.

1. \_\_\_\_\_ Heat comes from vibrating molecules.
2. \_\_\_\_\_ Molecules always vibrate at the same speed.
3. \_\_\_\_\_ The faster molecules vibrate, the less heat they give off.
4. \_\_\_\_\_ Temperature tells us how fast molecules vibrate.
5. \_\_\_\_\_ Temperature is measured in calories.
6. \_\_\_\_\_ We measure temperature with a barometer.
7. \_\_\_\_\_ Heat depends only on how fast molecules vibrate.
8. \_\_\_\_\_ Ice has heat.
9. \_\_\_\_\_ An ice cube has the same amount of heat as a block of ice.
10. \_\_\_\_\_ Heat energy is measured in calories.

**MATCHING** Match the two lists. Write the correct letter on the line next to each number.

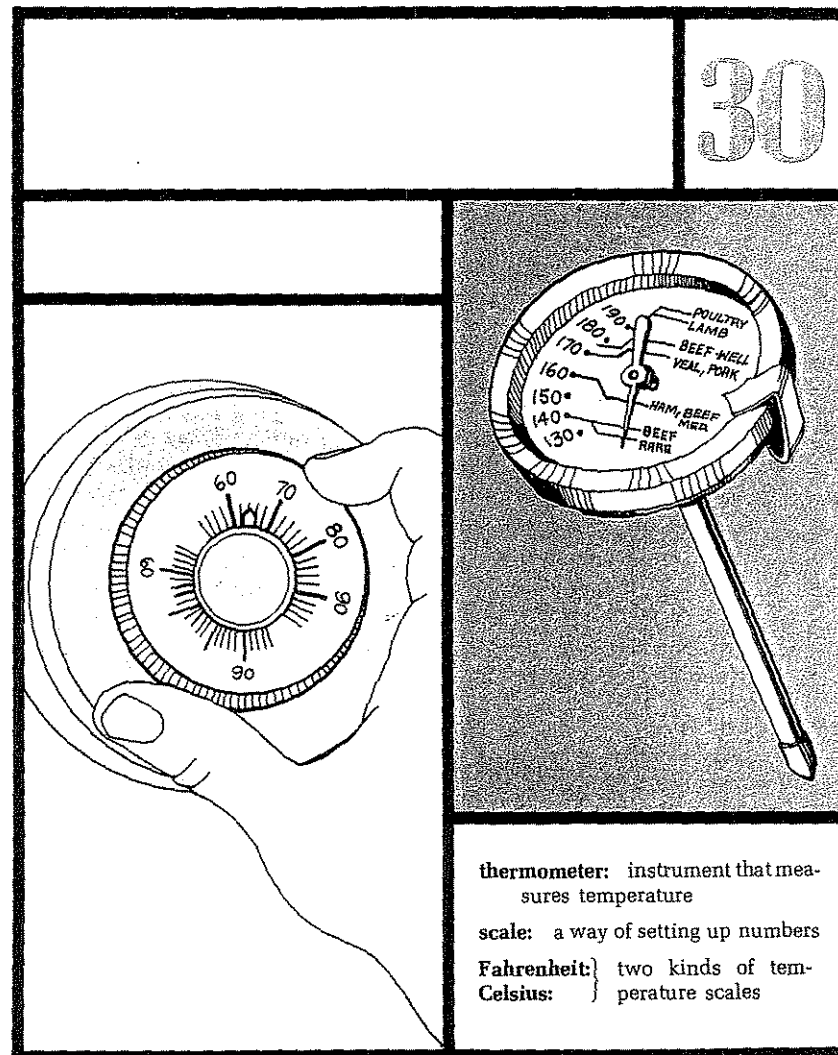
- |          |                      |                                                         |
|----------|----------------------|---------------------------------------------------------|
| 1. _____ | temperature          | a) depends upon how fast and how many molecules vibrate |
| 2. _____ | heat                 | b) measure of heat                                      |
| 3. _____ | degree               | c) related but not the same                             |
| 4. _____ | calorie              | d) measure of temperature                               |
| 5. _____ | temperature and heat | e) depends upon how fast molecules vibrate              |

**THROW ONE OUT!** In each of the following sets of terms, one of the terms does not belong. Circle that term.

- |                             |                   |                     |
|-----------------------------|-------------------|---------------------|
| 1. friction                 | sun               | source of most heat |
| 2. molecules vibrate faster | temperature rises | temperature drops   |
| 3. molecules vibrate slower | temperature rises | temperature drops   |
| 4. temperature              | degrees           | heat                |
| 5. heat                     | calories          | degrees             |

# HOW DOES A THERMOMETER WORK?

30



# AIM | How does a thermometer work?

Think of all the ways you use thermometers. They tell you indoor temperature and outdoor temperature. A thermometer in meat tells if the meat is cooked well enough. A thermometer in a refrigerator tells whether the refrigerator is cold enough. When you don't feel well, you take your temperature with a thermometer.

No matter what kind of thermometer you use, it works because of two facts you already know:

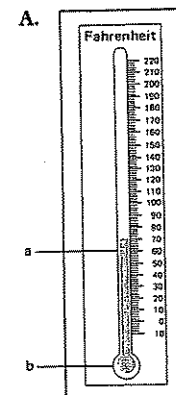
1. Matter expands when it is heated.
2. Matter contracts when it is cooled.

In most thermometers, the matter that expands or contracts is a liquid. The main part of a thermometer is a long closed tube. At one end the tube gets larger. This end is called the *bulb*. The bulb is filled with a liquid that runs part way up the tube. In most thermometers, the liquid is either *mercury* or *colored alcohol*.

1. When the liquid in a thermometer is heated, it expands. It *rises* in the tube.
2. When the liquid in the thermometer is cooled, it contracts. It *falls* in the tube.

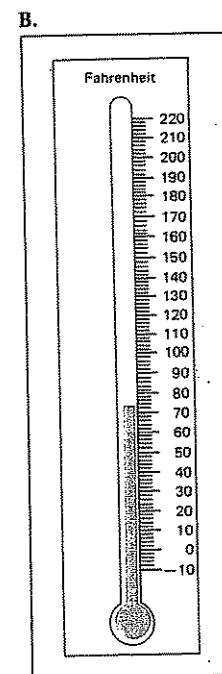
Numbers and lines on the side of the tube tell us the temperature in *degrees*. There are two popular temperature scales. In the United States, the *Fahrenheit* scale is often used. In most of the rest of the world, the *Celsius* scale is used. Scientists everywhere use the Celsius scale. The United States is switching to the Celsius scale. You may as well learn to use it now. You'll need it!

## WHAT DO THE PICTURES SHOW



I. Look at the thermometer in Figure A. Then answer the questions.

1. The tube is lettered a, b.
2. The bulb is lettered a, b.
3. Name two liquids that are used in liquid thermometers.  
\_\_\_\_\_
4. When heated, the liquid rises, falls in the tube.
5. When cooled, the liquid rises, falls in the tube.
6. This is a Fahrenheit, Celsius scale thermometer.



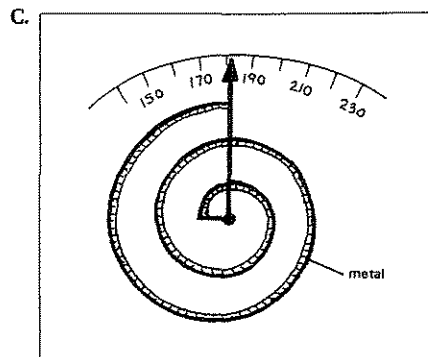
II. Look at the thermometer in Figure B. Then answer the questions.

The temperature on this Fahrenheit thermometer is 72 degrees. In symbol form it is written 72°F.

7. How do you think you write 72 degrees Celsius? \_\_\_\_\_
8. In this thermometer, how many degrees does each line stand for? \_\_\_\_\_
9. Take a guess! Do all thermometers have the same number of degrees between lines? \_\_\_\_\_
10. Write the following temperatures in symbol form:
  - a) twenty-two degrees Fahrenheit \_\_\_\_\_
  - b) one hundred degrees Celsius \_\_\_\_\_
  - c) minus five degrees Fahrenheit \_\_\_\_\_
  - d) seventy-nine degrees Fahrenheit \_\_\_\_\_
  - e) forty-four degrees Celsius \_\_\_\_\_

Some thermometers tell temperature because a metal coil inside them expands or contracts.

Oven and meat thermometers are examples.



**COMPLETING SENTENCES** Complete the sentences with the choices below. One of these may be used twice.

become smaller  
falls  
Fahrenheit  
cooled

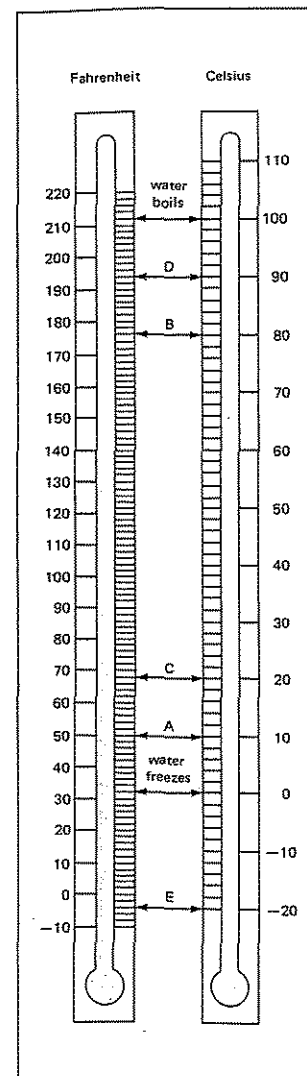
colored alcohol  
liquid  
thermometer  
rises

become bigger  
heated  
mercury  
Celsius

- We measure temperature with a \_\_\_\_\_.
- A thermometer works because matter expands when \_\_\_\_\_ and contracts when \_\_\_\_\_.
- There are two main kinds of temperature scales. They are \_\_\_\_\_ and \_\_\_\_\_.
- In the United States the \_\_\_\_\_ scale has been used most often.
- In most thermometers, a \_\_\_\_\_ is used.
- Two common liquids used in thermometers are \_\_\_\_\_ and \_\_\_\_\_.
- When heated, the liquid \_\_\_\_\_ in the thermometer tube.
- When cooled, the liquid \_\_\_\_\_ in the thermometer tube.
- Contract means to \_\_\_\_\_.
- Expand means to \_\_\_\_\_.

## WORKING WITH THERMOMETERS

The diagram below shows a Fahrenheit thermometer and a Celsius thermometer. See how the scales are different. Study them. Then fill in the temperatures below. Line up the numbers with a straight edge. Each line stands for two degrees.



| I. |               | Fahrenheit | Celsius |
|----|---------------|------------|---------|
| 1. | Water boils   |            |         |
| 2. | Water freezes |            |         |

| II. | Point on Thermometers | Fahrenheit | Celsius |
|-----|-----------------------|------------|---------|
| 3.  | A                     | 50°        |         |
| 4.  | B                     |            | 80°     |
| 5.  | C                     |            | 20°     |
| 6.  | D                     | 194°       |         |
| 7.  | E                     | -4°        |         |

- 86° F is the same temperature as \_\_\_\_\_ ° C.
- 104° F is the same temperature as \_\_\_\_\_ ° C.
- 50° C is the same temperature as \_\_\_\_\_ ° F.
- 10° C is the same temperature as \_\_\_\_\_ ° F.
- 40° C is the same temperature as \_\_\_\_\_ ° F.
- 60° C is the same temperature as \_\_\_\_\_ ° F.
- 158° F is the same temperature as \_\_\_\_\_ ° C.
- What temperature would you want it to be all the time?  
Write your answer in both Fahrenheit and Celsius. \_\_\_\_\_



**WORD SEARCH** The words in this list are hidden in the groups of letters. Try to find each word. Draw a line around each word. The spelling may go in any direction: up-and-down, across, or diagonally.

LIQUID  
CALORIE  
VIBRATE  
DEGREE  
MATTER  
ABSORB  
REFLECT

|   |   |   |   |   |   |   |   |
|---|---|---|---|---|---|---|---|
| B | R | O | S | B | A | Q | L |
| R | E | T | T | A | M | V | D |
| Q | F | S | A | P | I | P | E |
| L | L | T | I | B | S | O | L |
| D | E | G | R | E | E | L | F |
| I | C | A | O | L | M | I | E |
| P | T | D | I | U | Q | I | L |
| E | I | R | O | L | A | C | R |

**REACHING OUT** Why is water not used in thermometers?

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